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DESIGN OF SMALL WOODEN HEAD FRAMES

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W. W. STALEY

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DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

DESIGN OF SMALL WOODEN HEAD FRAMES [1]

By W. W. Staley [2]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6943".

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INTRODUCTION

This paper discusses the design of small head frames that will fill
the needs of prospectors and small operators whose operations are conduct
ed through shafts. The head frames considered were designed to handle r
atively small tonnages. It was assumed that the shafts in which buckets
are used would not exceed 300 feet in depth and that not over 60 tons o
rock would be hoisted in 14 hours. In the design of the larger head fra
a hoisting capacity of about 250 tons per 6 hours from a depth of 300 to
500 feet was assumed. Under these conditions, hoisting speed, rate of a
celeration, and weight of rope have a negligible effect on the head fram
design and, therefore, have been ignored in the following discussion.

Because timber is relatively cheap and easily obtained in most mini
areas, the discussion has been confined to timber construction.

Two general types of head frames are discussed - those for single-c
partment shafts, in which buckets are used, and those for three-compartm
shafts (two employed for hoisting), in which hoisting is done in balance
in cars, or cages, or skips. These two types are considered for both
vertical and inclined shafts.

STRENGTH OF NATIVE SPECIES OF TIMBER

In designing a head frame of any consequence it is necessary first to cide upon the species of timber from which the structure is to be built. is is necessary because the stresses the various woods will withstand ry rather widely. In very modest structures for small-scale development is is of little importance. In larger ones it should be considered. e data in table 1 are given as a guide to the relative strength of ber.[3]

The basic allowable tensile stress for steel used in timber construcon is as follows:

Long bolts and tie-rods	16,000 lb. per sq. in.
Steel plates for bearing and bending	16,000 lb. per sq. in.
Hoisting ropes	Ultimate breaking strength as given for each rope by the manufacturer.

The formula generally used for calculating the strength of columns ose length is greater than 15 times the least dimension is

$$P/A = K (1 - L/60D)$$

ere

P = total load supported by timber, pounds;

A = area, square inches;

K = basic stress parallel with grain, pounds per square inch;

L = unsupported length, inches;

D = least transverse dimension, inches.

STRESSES THAT ACT ON SMALL HEAD FRAMES

The stresses in a head frame result from[4] (1) dead loads, (2) live ads, and (3) wind loads.

Dead-load stresses result from the weight of the head frame, sheave eels, and attached structures, such as ore bins. In the case of an ore supported by the head frame, 25 percent of the actual weight of its ntents should be added in entering the figures in the calculation, as the ing ore has the characteristics of a live load. It is not recommended at ore bins be attached to the head frame.

U. S. Department of Agriculture, Wood Handbook: September 1935.

Staley, W. W., Mine Plant Design: McGraw-Hill Book Co., Inc., New York, 1936, p. 90.

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TABLE 1. - Timber likely to be available for head frame construction

Species	Locality	Basic allowable stress, pounds per square inch							
		Always dry		Occasionally wet		Continuously wet		Green	
		Parallel with grain, K	Perpendicular to grain	Parallel with grain, K	Perpendicular to grain	Parallel with grain, K	Perpendicular to grain	Parallel with grain, K	Perpendicular to grain
Douglas fir(red fir):									
Coast Region	Northwest; northern Rocky Mountain.; Northern Calif.;	1,300	275	1,000	210	900	180	700	180
Rocky Mountain Region	western U.S., except Nevada	1,000	200	750	150	700	130	500	130
Western hemlock	Pacific coast Northern Rocky Mountain	1,000	200	750	150	700	130	500	130
Larch, tamarack	Northern Rocky Mountain	1,300	275	1,000	210	900	180	700	130
Pine(Ponderosa, yellow, bull, Idaho white, lodgepole, black, jack)	All western U. S.	800	150	600	110	500	100	400	100
Pine, southern, yellow, longleaf	Southern U.S.	1,300	275	1,000	210	900	180	700	180

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The live-load stresses are caused by the weight of the cage, car and nents (or skip and contents), and rope; as the head frame should be ong enough to withstand any possible load, the breaking strength of the e is considered as an additonal live load. The distribution of the live d among the members of the head frame depends on the angle the rope es with the horizontal.

Wind-load stresses usually are based on assuming that the head frame completely housed and that the horizontal pressure is 30 pounds per are foot. This load, however, can be disregarded for the type of head e under discussion; an ample factor of safety is provided by the method calculating live-load stresses, and the sizes of members will be based the breaking strength of one rope with a cage and car or a skip on the er rope.

Determination of Stresses in the Head Frame

It is not necessary to make a critical examination of the stresses in h member of a small head frame, as would be advisable for large wooden or el head frames.

The first step is to determine the total suspended weight on the rope. m this the rope size is decided upon. For the size of operations under con- eration a safety factor of 7 has been taken. The total load times 7 will e the minimum breaking strength of the rope to be used. For example, a ket with contents and crosshead weighs 1,600 pounds; 1,600 x 7 = 200 pounds.

Consulting a rope manufacturer's handbook, we find the nearest size to a 6 x 19, 3/8-inch-diameter rope, with a breaking strength of 12,600 nds. For large ropes (greater than 1 inch) and deep shafts (deeper than feet) the weight of the rope and the force to accelerate the load and rope must be considered in selecting the rope size.[5]

Figures 1 and 2 show the essential features of A-type head frames. batter of the posts shown (3 inches per foot) need not be adhered to ictly. It may be reduced to 2 inches per foot, provided the front posts l still clear the shaft collar. The resultant is found by determining reactions on the ends of the sheave girder that would occur in breaking pe on one side with an empty cage and car on the other side, these ces being applied at the sheave wheels. The resultant acts along a line t bisects the angle between the rope in the shaft and the rope to the m. In the present paper the rope is assumed to make an angle of 45° with horizontal in all cases. The resultant is resolved into two components, parallel to the back posts and the other parallel to the front posts. resulting components represent the forces to be resisted by the respec- e posts. There are no resulting hoisting stresses set up in the bracing struts of the A-frame.

Staley, W. W., work cited in footnote 4, p. 80.

Figure 1-B shows, diagrammatically, the solution for the resultant an the stresses in the posts. This diagram is constructed in the following manner: The rope used is 3/8 inch in diameter and has a breaking strength of 12,600 pounds. For the simple head frame under discussion there is only one rope. The total possible load, therefore, will equal the breaking strength of this rope. The A-frame is drawn to a suitable scale. The length of the posts is that represented by the slant height, which is slig ly more than the vertical height. As a rule no appreciable error results if the vertical height is used. Next, the rope is drawn from the apex of the A-frame, and the desired angle with the horizontal (in this case 45°) is thus made. Using any convenient distance (usually 1 inch), lay off equal distances on both the front and back portions of the rope. By means of triangles a parallelogram (as shown by the dotted lines in figure 1-B) is drawn. The length of the long diagonal through the parallelogram represents the factor by means of which the resultant is found. For example in the figure 1-inch sides were used for construction purposes. One inch then equals 12,600 pounds, which is equivalent to the breaking strength of a 3/8-inch rope. On scaling the diagonal it was found to be 1.85 inches. The resultant is equal to 1.85 x 12,600 = 23,300 pounds. To find the stresses in the posts a stress diagram is drawn. By means of triangles, R on the A-frame, is transferred to one side. To some convenient scale its length (magnitude) is made equal to 23,300 pounds. Lines parallel to the back and front posts are transferred as shown. Scaling these lines and co verting to pounds give the stresses in the posts. As there are two back posts and two front posts, the load on one back post is equal to 1/2 x 17,500 = 8,750 pounds; and on one front post it is 1/2 x 6,900 = 3,450 pounds. No stresses result in the struts and bracing.

To find the stresses that act in the bracing and struts of the trans verse frames, the resultant reaction arising from the breaking rope and the cage and car is resolved into front- and back-post components in the same manner employed for components in the front and back posts. A stre diagram is then drawn for each frame, and the resulting stresses are dete mined. These stresses are very small when compared with the stresses in the posts and for present purposes need not be determined for small timb head frames subjected to relatively light loads. Because of the framing and connecting of the timbers a larger piece is required than is indicate by the calculated stresses. In structures requiring posts 8 by 8 inches and up to 14 by 14 inches, the struts may safely be made of material half size of the posts. For example, with 8- by 8-inch posts use 4- by 8-inc material for the compression members (struts); with 12- by 14-inch posts use 6- or 8- by 14-inch material. For the tension members (bracing) ti should be employed. For the smaller frames, 3/4-inch rods are suitable, and for the larger, 1-inch rods.

To determine the size of the posts, use is made of the straight-lin column formula:

$$P/A = K - K\ L/60D,$$

ere

P = total load column will support, pounds;

A = cross sectional area of column, square inches;

K = basic allowable compressive stress parallel to the grain for the particular wood under consideration (see table 1), pounds per square inch;

L = unsupported length of column, inches;

D = least dimension of rectangular column, or diameter of round column, inches.

For example, if we assume a length of 13 feet for the column and the sic stress for pine that are given in table 1, and assume a stress of ,000 pounds to be resisted by the column, we can find the size of timber using the above column formula.

Trying an 8- by 10-inch section

$$\frac{P}{8 \times 10} = 800 - \left(800\ \frac{13 \times 12}{60 \times 8}\right) = 540 \text{ pounds per square inch}$$

$$P = 8 \times 10 \times 540 = 43{,}200 \text{ pounds.}$$

An 8- by 8-inch timber would withstand but 34,560 pounds, so that one ty 10-inch in size must be used.

eave Girders and Sheave Posts

Sheave girders and posts must be designed to resist bending. The reltant of the breaking-rope strain is resolved into its vertical and horintal components. These two forces are considered as acting at the center f the sheave. This is not strictly true, for actually one-half of each of ese forces acts at the journals of the sheave wheel. By assuming the ction at the center, the calculations are simplified, although a somewhat rger force must be resisted, which may require a slightly larger timber; herefore, the assumption is on the safe side. The sheave girder is assumed o act as a simple beam. The reactions of the forces that act at the sheaves re determined, and the girder is designed to resist bending, based on the aximum reaction.

A formula suitable for this is

$$M/f = bd^2/6,$$

$$d = \sqrt{6M/fb},$$

where

M = bending moment, inch-pounds;

f = working stress in extreme fiber, pounds per square inch (see table 1, columns K), for steel, $f = 16{,}000$ for our purpose;

b = breadth of section, inches;

d = depth (face parallel to force acting) of section, inches.

The above formula is sometimes expressed as $S = bd^2/6$, where $S = M/f$ = the section modulus.

The bending moment M is found by multiplying the reaction (expressed in pounds) at the center of the support (end of girder) by the distance f the center of the support, in inches, to the center of the sheave wheel. Assuming a breadth of beam b, which details well with the dimension of the posts, the depth can be found.

Example:

A sheave girder is 8 feet between centers of supports. The centers of the sheave wheels are 1.5 feet from the ends. The loads on the sheave wheels are 8,000 pounds on the left side and 30,000 pounds on the right side. The breadth of the beam is taken as 12 inches. What should be its depth?

The maximum reaction will occur on the right side. It is

$$R = \frac{1.5 \times 800 + 6.5 \times 30{,}000}{8} = 25{,}900 \text{ pounds.}$$

The maximum bending moment will occur at the point of application of 30,000-pound load:

$$M = 25{,}900 \times 1.5 \times 12 = 456{,}200 \text{ inch-pounds.}$$

The size of the girder may safely be based on 80 percent of this fig

$$466{,}200 \times 80 \text{ percent} = 372{,}960 \text{ or } 373{,}000 \text{ inch-pounds.}$$

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Assuming the girder is to be made of a good grade of Douglas fir,

f = 1,300 pounds per square inch.

$$d = \sqrt{\frac{6 \times 373,000}{1,300 \times 12}} = 12 \text{ inches.}$$

The girder would be a 12- by 12-inch timber. The sheave posts are lected in the same manner. In many cases the size of the timber selected st be increased because of insufficient bearing area. For example, the rce exerted by the back post of a head frame is 40,000 pounds; the post an 8- by 8-inch timber. It is purposed to rest the end of the post on 8 by 16-inch timber.

The area of the 8 by 8 is 64 square inches. In end bearing it will end 1,300 x 64 = 83,200 pounds.

In bearing perpendicular to the grain, the sill will withstand 275 64 = 17,600 pounds. This is only 44 percent of the load it must take. there is no option but to use a wooden sill, then the post must be in- eased in cross section to give a bearing area of 40,000 divided by 275 = 6 square inches; a 12- by 12-inch or 10- by 14- inch timber could be used. alternative would be to employ a steel or cast-iron bearing plate of 6 square inches net area and appropriate thickness.

Steel Plates and Bolts for Connecting Sheave Posts to Sheave Girders or Sheave Girders to Main Posts

Plates for this purpose are shown in figures 11, 12, and 16. Their aring area on the wood, effect of shear on the wood, and the thickness to sist bending in the plate must all be found.

For example, a pair of sheave posts must resist a load of 24,000 pounds. may be assumed that each post will take 12,000 pounds of this. The re- tion at the ends will be 6,000 pounds, as the load occurs at the center. shown in the drawings, there is a plate on each side of the sheave post nnected by a bolt. When the load comes on the post, half of the plate may ve to resist the full 6,000 pounds. The bearing area of the plate will be lculated on the basis of a 6,000-pound load, as will shear in the timber. cause of the connecting bolt, both plates will tend to resist bending. e thickness of the plates will be based on a load of 1/2 x 6,000 = 3,000 unds.

ea of Plate

When Douglas fir, structural grade is used, with bearing of 300 pounds r square inch perpendicular to the grain, 6,000/300 = 20 square inches re required.

The sheave posts are 8- by 10-inch. One dimension of the plate is 8 inches. The other is 20 ÷ 8 = 2.5; say 3 inch. This represents half of the width of the plate. The plate will be 2 x 3 = 6 inches wide and its le that shown in the illustrations.

Shear in Posts and Girders

For shear, 170 pounds per square inch is used as the safe load. 6,000 = 35.3 square inches. Both the post and the girder are 10 inches deep. The required width is 35.3/10 = 3.53 inches. The post is 8 inches wide, and th plate extends over a still greater length on the girder, so each is safe f shear.

Thickness of Plate

The plate extends 3 inches on each side of the center of the connectin bolt. The acting force is 3,000 pounds. This gives a bending moment o

3,000 x 3 = 9,000 inch-pounds.

From

$M/f = bd^2/6$, taking f = 16,000 for steel,

$$d = \sqrt{\frac{6 \times 9{,}000}{16{,}000 \times 3}} = 1.06 \text{ or } 1\ 1/8\text{- inch plate.}$$

Connecting Bolts

The tensile stress on the bolt is 6,000 pounds.

6,000/16,000 = 0.375 square inch net area (area at the base o the thread).

The nearest listed size to this is 7/8 inch. A 1-inch diameter bolt will be used, as that is most likely to be carried in stock.

Bolts Tying Top and Bottom Sheave Girders Together

For the vertical and horizontal components of the resultant to be distributed to both girders, and also for the sheave posts to be firmly h in place, the girders are connected by bolts. Taking the net vertical co ponent that acts on the girder as 32,200 pounds, with one bolt beside eac sheave post (see figs. 6, 16, 11, and 12), each bolt will withstand

32,200/2 = 16,100 pounds.

Its net area is 16,100/16,000 = 1 square inch.

A 1 3/8-inch diameter rod is necessary.

her Bolts

The number of bolts for fastening sheave girders to posts and sheave sts to girders may be found by use of tables[6] 2, 3, and 4. Table 3 is r connections of the type shown in figure 4; table 4 for connections shown figure 11, which illustrates the connection of the sheave girder to the ont post, or (fig. 10) the sheave posts to the girders. If metal splice-ates are used for tension joints, like that shown in figure 4 the full lues in the table are used; when wooden splice-plates one-half the thick-ss of the main member are used, 80 percent of the values are taken. For ample, the total reaction at the ends of the top and bottom sheave girders 44,200 pounds. Assuming that this is taken equally by each girder, bolts st be selected to sustain 44,200 ÷ 2 = 22,100 pounds. The girder is 10 ches thick.

Trying a 1-inch bolt, L/D = 10/1 = 10. From table 4, group 3, the ef-ciency equals 67.2 percent. The bolt factor for a 1-inch bolt = 1.27 from e same table.

From table 2, the basic stress perpendicular to the grain is 275 pounds r square inch:

275 x 67.2% x 1.27 = 235 pounds per square inch.

This allowable stress, multiplied by the length of the bolt and di-ter of the bolt, gives the load safely taken by each bolt:

235 x 10 x 1 = 2,350 pounds per bolt.

Number of bolts required is 22,100/2,350 = 9.4, or 10 bolts.

Four bolts will be put through the girder and the remaining six through e supporting block.

eave Post Connections

The vertical component is 57,200 pounds. There are two posts, rep-senting four connections. 57,200/4 = 14,300 pounds at each end.

. S. Dept. of Agriculture, Wood Handbook: September 1935, pp. 131, 132.

TABLE 2. - Basic allowable stresses for calculating safe loads for bolted joints1/

Group	Soft woods (conifers)	Basic Stress	
		Parallel with the grain, pounds per square inch	Perpendicular to the grain, pounds per square inch
1	Cedar, northern and southern; fir, balsam and commercial white; hemlock, eastern; pine, lodgepole, Ponderosa, sugar, northern white, and western white; spruce, Englemann, red Sitka, and white	800	150
2	Cedar, Alaska, incense, Point Orford, and western red; Douglas fir (Rocky Mountain); hemlock, western; pine, Norway	1,000	200
3	Cedar, eastern red; cypress, southern; Douglas fir, coast; larch, western; pine, southern yellow; redwood; tamarack	1,300	275

1/ For dry, seasoned timbers; for timbers occasionally wet but quickly dried use three-fourths listed value; for timbers that are damp or w most of the time usetwo-thirds the listed basic stress.

TABLE 3. - Percentage of basic stress parallel with the grain for calculating safe bearing stresses under bolts

gth of bolt in main ber, divided by its meter (L/D)	Percentage of basic stress for common bolts (yield point 45,000 pounds per square inch)		
	Group 1 woods	Group 2 woods	Group 3 woods
	100.0	100.0	100.0
5	100.0	100.0	100.0
	100.0	100.0	100.0
5	100.0	100.0	99.7
	100.0	100.0	99.0
5	100.0	99.3	96.7
	99.5	97.4	92.5
5	97.9	93.8	86.8
	95.4	88.3	80.0
5	91.4	82.2	73.0
	85.6	75.8	67.2
5	79.0	70.0	62.0
	73.4	65.0	57.6
5	68.5	60.6	53.7
	64.2	56.9	50.4
5	60.4	53.5	47.4
	57.1	50.6	44.8
5	54.1	47.9	42.4
	51.4	45.5	40.3
.5	48.9	43.3	38.4
	46.7	41.4	36.6
.5	44.7	39.6	35.0
	42.8	37.9	33.6
.5	41.1	36.4	32.2
	39.5	35.0	31.0

TABLE 4. - Percentage of basic stress perpendicular to the grain used in calculating safe bearing stress under bolts

Length of bolt in main member, divided by its diameter (L/D)	Percentage of basic stress for common bolts (yield point 45,000 pounds per square inch		
	Group 1 woods	Group 2 woods	Group 3 woods
1 to 5, inclusive	100.0	100.0	100.0
5.5	100.0	100.0	100.0
6	100.0	100.0	100.0
6.5	100.0	100.0	99.5
7	100.0	100.0	97.3
7.5	100.0	99.1	93.3
8	100.0	96.1	88.1
8.5	98.1	91.7	82.1
9	94.6	86.3	76.7
9.5	90.0	80.9	71.9
10	85.0	76.2	67.2
10.5	80.1	71.6	62.9
11	76.1	67.6	59.3
11.5	72.1	64.1	55.6
12	68.6	61.0	52.0
12.5	65.3	58.0	49.0
13	62.2	55.3	45.9

Diameter of bolt, inches	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/2
Diameter factor	2.50	1.95	1.68	1.52	1.41	1.33	1.27	1.19	1.14	1.10	1.07	1.03

Trying 1 1/4-inch-diameter bolts, the post being 8 by 10 inches,

L/D = 10/1.25 = 8. The efficiency = 88.1. The bolt factor = 1.19.

Stress per bolt = 275 x 88.1% x 1.19 x 10 x 1.25 = 3,610 pounds.

14,300/3,610 = 4 bolts.

nnection of Struts to Main Posts

If a connection of this kind becomes desirable it may be made in one of o ways: By bolts passing through one member at an angle, which requires e use of an angle washer, or by steel splice plates, which necessitate o plates and four bolts (two in the strut and two in the post). Quarter-ch plates and 3/4-inch bolts are suitable in either case.

Built-Up Sections and Spliced Members

ilt-Up (Laminated) Sections

It is thought by many that built-up sections are as strong as or strong- than the equivalent area-size solid piece. This is not true in all cases[7]. ı the case of beams made of uniform planks with vertical laminations, the rength of the laminated beam is probably as great as that of a solid timber equivalent dimension. For those members of a head frame that act as beams heave girders and sheave posts) it is not recommended that they be of laminated construction. A well-seasoned solid piece, free from knots and cracks, ould be used.

For the posts and struts, laminated members may be used, provided the dividual planks are selected carefully for uniformity and freedom from rge knots and cracks. The load they will support depends on what is called e L/D (slenderness) ratio, where L is the unsupported length, in inches, d D is the least transverse dimension, in inches. For example, take a 0-foot column made of 8- by 10-inch timber. The L/D ratio is 10 x 12/8 15. For this ratio the efficiency of the built-up column is a certain percentage of a solid 8- by 10-inch column 10 feet long.

Table 5 gives the efficiency of laminated columns to solid timbers for iven L/D ratios[8].

/ U. S. Dept. of Agriculture, Wood Handbook: September 1935, p. 156.

/ U. S. Dept. of Agriculture, Wood Handbook: September 1935, p. 165.

TABLE 5. - Efficiency of laminated columns

L/D ratio	Percent of solid column strength
6	82
10	77
14	71
18	65
22	74
26	82

Note: For ratios over 10, the efficiency applies to columns built up of individual pieces, full length, or those in which butt-jointed pieces are used.

Figure 3 shows the construction of a laminated column suitable for head frames.

In the head frame shown in figure 6 the greatest unsupported length of the back post is 13 feet 9 inches, or 165 inches. If the back post were made of solid timber, and 8- by 8-inch stick would be large enough:

$$\frac{P}{8 \times 8} = 1{,}200 - \frac{20 \times 165}{8}$$

$$P = 50{,}400 \text{ lb.}$$

If made of laminated material,

$$\frac{L}{D} = \frac{165}{8} = 20.625.$$

From table 5, the efficiency for this ratio is, by interpolation, about 70 percent. The area of laminated timber must then be $8 \times \frac{8}{0.7} = 91$ square inches. $\sqrt{91} = 9.5$; a 10- by 10-inch section would be necessary. Five 2- by 10-inch planks well spiked and bolted together would suffice.

Because of the great length of the front and back posts and also the lower struts on the inclined head frame, it may become necessary to splice these members. If this is necessary with regard to the posts, the splice should occur near the connection of the strut or bracing with the post. Figure 4 shows the details of making such a splice. The head frame shown in figure 5 has a splice of this type. For splicing the posts or struts (these are compression members and act as columns; see fig. 1) four bolts on each side of the splice are sufficient. Eight 3/4-inch bolts (fig. 4) suffice for 4" x 6" to 4" x 10", 6" x 6" to 6" x 12", and 8" x 8" to 8" x 12" timbers (fig. 4).

DESIGN OF A SMALL SINKING HEAD FRAME

(May also be used for small operating properties)

Figure 8 and figure 9 show respectively a small sinking head frame for a vertical and an inclined shaft. Assume that a head frame is to be selected for a vertical or inclined shaft and that ore is to be hoisted in a 10-cubic foot bucket, the size of which is as follows: Top, 25 inches; center, 26 inches; bottom, 24 inches; height, 36 inches. This bucket weighs 350 pounds. A crosshead is used in the vertical shaft arrangement that weighs approximately 250 pounds. The weight of the ore in the bucket is 1,000 pounds. The allowable compressive stress in the wood parallel to the grain is 800 pounds per square inch.

Rope

Total weight hoisted = 1,000 + 350 + 250 = 1,600 pounds.

Using a factor of safety of 7 for the rope, 1,600 x 7 = 11,200 pounds, or 5.6 tons, which is the minimum ultimate strength of the rope. Roebling's Blue Center[9] or American Steel & Wire Co. Monitor Silver Strand[9], 6 x 19, 3/8-inch-diameter rope is satisfactory. They have an ultimate strength of 6.3 tons. The design of the head frame, therefore, will be based on the breaking strength of this rope.

Sheave Wheel

To avoid excessive bending stresses and wear on the rope, the diameter at the sheave groove should be about 48 times the diameter of the rope. 48 x 3/8 = 18 inches groove-diameter of the sheave wheel.

Head Frame (Vertical Shaft)

To provide plenty of dumping room for the bucket, the height to the center of the sheave wheel should be about 20 feet. This may be varied to suit local conditions as long as the vertical distance of 10 feet between the horizontal struts is not exceeded. If the 10-foot panel interval is exceeded, the size of the posts may have to be increased. If a batter of 3 inches per foot is assumed for the posts, the width at the bottom will then be 13 feet. To keep the resultant of the rope-load inside the head frame, the depth (distance from front post to back post) is made 12 feet. The width between posts at the top is 14 inches.

The selection of the timber will be based on the breaking strength of the rope, in accordance with the usual practice. The angle of the rope (sheave wheel to drum) with the horizontal is 45°. (See figs. 1 and 2).

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[9] Roebling's Sons catalog, Pacific Coast edition, Jan. 1, 1930.
American Steel & Wire Co. catalog, May 1931.

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The resultant, based on the breaking strength of a 3/8-inch rope (see fig. 1-B) is 23,300 pounds. The force that acts on the back posts is 17,500 pounds and on the front post 6,700 pounds. There are two front and two back posts, so that each post takes half of these loads.

A head frame of this type is likely to be built of whatever material is most readily available. A basic allowable stress of 800 pounds per square inch will be used. Trying a 4- by 6- inch timber,

P(4 x 6) = 800 - 800 x 132 divided by(60 x 4)

P = 8,640 pounds.

This just barely meets the requirements as determined by substituting in the formula:

17,500 x 1/2 = 8,750 pounds.

The load on the **front post is** very **small.** On the basis of the column formula a small post is required. It will be convenient, because of detailing, to make it 4 by 6 inches.

Sills

To tie the posts together at the bottom, the construction shown in figures 8 and 9 may be used. The longitudinal sills must have a large enough cross section to resist shearing and crushing. The greatest load is on the back posts. The bearing area required is 8,750/150 = 58.3 square inches.

From this we see that if a low-strength wood is used for the sills the back posts would have to be increased to 6 by 10 inches in cross section. By using a high-strength wood, 8,750/275 = 31.8 square inches are required. The back posts must be increased to 6 by 6 inches and be made of fir, tamarack, or yellow pine. The width of the sill is 6 inches. The depth (to resist shear) is 31.8/6 = 5.3 inches. To this must be added 2 inches for gaining the post into the sill. The depth must therefore be 5.3 + 2 = 7.3 inches. The sills will then be of 6- by 8-inch timbers.

Additional 4- by 6-inch timbers will be bolted transversely across the bottoms of the front and back posts. The posts are held to the sills by bolts as shown.

Small Head Frame for an Inclined Shaft

Figure 9 gives the details for this type of head frame, and figure 9a gives detail for the guides or skids. The dimensions shown may be altered to suit the particular bucket used.

Table 6 gives the essential timber dimensions for sinking head frames for a variety of bucket sizes.

A-TYPE HEAD FRAME (FIGS. 2, 5, 6, 7, 10, 11, and 12)

Before proceeding with the selection of the head frame for this arrangement, the detail of the shaft collar must be decided upon. This is necessary to provide for head frames of proper bottom width so that the posts will not crowd the shaft collar and so that the sheave wheels may be centered properly and the rope hang vertically in the center of the compartment. Figure 7 shows the collar layout for the examples of vertical shaft head frames to follow.

As the head frame is to be designed to withstand stress in excess of that which will break the rope, it is first necessary to determine the load to be handled.

A cage for the compartment shown, which will handle one 20-cubic foot car, will be assumed.

Load

	Pounds
Cage, 4 feet 8 inches by 3 feet 4 inches; weight........	1,500
Car, length 52-3/4 inches; width 34 inches; height above rails 42-1/4 inches; weight..................	1,000
Contents...	2,000
Total..	4,500

Rope

4,500 x 7 = 31,500 pounds minimum ultimate strength of rope. The nearest size of the best grade of 6 x 19 rope is 5/8 inch, and it has a breaking strength of 16.6 tons, or 33,200 pounds.

Sheave Wheels

48 x 5/8 = 30 inches groove diameter. The outisde diameter is 34 inches.

Head Frame

Height to center of sheave wheel is 36 feet. Batter of posts, about 3 inches per foot.

TABLE 6. - Size of members for sinking head frames, with various-size buckets[1]

Bucket		Approximate weight of bucket contents, and crosshead	Size of rope, inch.	Sheave, groove diameter, inches	Posts[2]							
					Rectangular section, inches				Round section, diameter inches[3]			
					Dry, f=1000		Green, f=500		Dry, f=1000		Green, f=500	
Capacity, cu. ft.	Weight, lb.				Front	Back	Front	Back	Front	Back	Front	Back
5	270	1,000	5/16	16	4 x 6	6 x 6	4 x 6	6 x 8	5	5	8	8
6	280	1,100	5/16	16	4 x 6	6 x 6	4 x 6	6 x 8	5	5	8	8
7	300	1,200	5/16	16	4 x 6	6 x 6	4 x 6	6 x 8	5	5	8	8
8.5	340	1,400	5/16	16	4 x 6	6 x 6	4 x 6	6 x 8	5	5	8	8
9	350	1,500	3/8	18	4 x 6	6 x 6	6 x 8	8 x 8	6	6	8	8
10	350	1,600	3/8	18	4 x 6	6 x 6	6 x 8	8 x 8	6	6	8	8
12	400	1,900	3/8	18	4 x 6	6 x 6	6 x 6	8 x 8	6	6	8	8
16	450	2,400	7/16	18	4 x 6	6 x 8	6 x 8	8 x 10	7	7	9	9

[1] Struts and bracing same size for all. Use dimensions shown in figures 2 and 9.
[2] Wood with a basic stress of 800 pounds per square inch may be used without altering sizes shown.
[3] Diameter given for section at the middle of the stick.

Top

The distance between centers of the hoisting compartments is 4 feet 10 inches, or 58 inches. To this must be added clearance for sheaves and construction outside the centers. On the center line of the sheaves the width is approximately 8 feet 10 inches.

Width

With a batter of 3 inches per foot, the width is 3 x 36 = 108 inches = 9 feet.

2 x 9 feet + 8 feet 10 inches = 26 feet 10 inches. This is greater than necessary. In order to clear the shaft collar, only 22 feet are required. The width will therefore be 22 feet inside the posts.

Depth

The position of the resultant (rope angle, 45°) shows that a depth of approximately 18.2 feet is satisfactory.

Panels

A panel spacing (distance between horizontal members) of 12 feet would be satisfactory.

Stresses

The resultant of the forces acting is 49,100 pounds. This is found by considering one cage and car and one cage loaded with the rope breaking. The stresses in the back post are 39,100 pounds, and in the front post 11,200 pounds. The vertical component of the resultant of the breaking rope is 57,200 pounds, and the horizontal component is 24,000 pounds.

Back Post

The maximum length of an unsupported section is 13 feet 9 inches or 165 inches. Trying an 8- by 8-inch timber with a basic allowable stress of 1,200 pounds per square inch

$$P/(8 \times 8) = 1{,}200 - 1{,}200 \times 165/(60 \times 8)$$

$$P = 50{,}400 \text{ pounds.}$$

A 6- by 8-inch timber is too small, so that an 8- by 8-inch section must be used. An 8- by 8-inch piece with a basic allowable stress as low as 900 pounds per square inch would prove satisfactory.

Front Post

Because of sheave girder connections and connection of posts, an 8- by 8-inch timber will be used, although on the basis of the stress (11,200 pounds) one much smaller could be used.

Bracing and Struts

Maximum compressive stress is 1,900 pounds. The maximum length of the member is 204 inches. Because of connections to the posts, a 4- by 8-inch piece will be used. It will stand a force of 5,800 pounds. (For exceptions to this size see figures 5 and 6.)

Rods

The maximum tensile stress is 3,200 pounds:

$$3{,}200/16{,}000 = 0.2 \text{ square inch.}$$

A 5/8-inch-diameter rod, after threading, has a net area of 0.202 square inch. The 3/4-inch rod is more likely to be carried in stock, so that it will be used.

Sheave-Girder Details

The sheave girder, sheave posts, and their connections are found as previously discussed. Details of constructing three types of girders are shown in figures 10, 11, and 12. Refer also to tables 7, 8, and 9.

FOUR-POST HEAD FRAMES (FIGS. 13 AND 14.)

The main members (posts, struts, and bracing), with few exceptions, are the same size as for the simple A-frame. The exceptions may be found by consulting the illustrations. Figure 14 is not, strictly speaking, a four-post head frame. There are only two front posts instead of four, as shown in figure 13. The sheave-wheel support, however is the same as that shown in figure 13, so for that reason it is classed as a four-post, or semi-four-post head frame.

The selection of the members for supporting the sheave wheels for this type of frame presents a somewhat different problem than heretofore discussed. It is in many ways simpler and more satisfactory than the A-type, but the total amount of timber for such a head frame is a little larger, whereas the total cost is slightly less. The lower cost results because not so much iron is required. The 8- by 8-inch cap is put in merely to tie the posts together at the top. It is attached to the posts by means of strap bolts and drift bolts (see figure 15). In order that the size of the transverse sheave girders may be reduced, diagonal struts supporting them at their centers and resting on the top horizontal struts are used. A pair of these diagonals is placed in the plane of the two front posts and another in that of the two middle posts.

TABLE 7 - Size of material for A-type head frames with varying loads, vertical shaft. Dry timber (for bolts, see table 8.)

pe ll, nds	Timber, kind	Posts, inches		Sheave girders, inches	Sheave posts, inches	Struts or timber bracing, inches	Bracing (tie-rods), diameter, inches
		Front	Back				
00	Douglas fir, coast	8 x 8	8 x 8	10 x 12	8 x 10	(4 x 8 (8 x 8	3/4
	Douglas fir, mountain .	8 x 8	8 x 8	10 x 12	8 x 10	do.	do.
	Hemlock	8 x 8	8 x 8	10 x 12	8 x 10	do.	do.
	Tamarack	8 x 8	8 x 8	10 x 12	8 x 10	do.	do.
	Pine	8 x 10	8 x 10	12 x 12	12 x 10	do.	do.
	Pine, southern yellow .	8 x 8	8 x 8	10 x 12	8 x 10	do.	do.
500	Douglas fir, coast ...	8 x 10	8 x 10	10 x 12	10 x 12	do.	do.
	Douglas fir, mountain .	8 x 10	10 x 10	10 x 12	10 x 12	(4 x 10 (10 x 10	do.
	Hemlock	8 x 10	10 x 10	10 x 12	10 x 12	do.	do.
	Tamarack	8 x 10	8 x 10	10 x 12	10 x 12	do.	do.
	Pine	8 x 10	10 x 10	12 x 12	12 x 12	do.	do.
	Pine, southern yellow .	8 x 10	8 x 10	10 x 12	10 x 12	do.	do.
500	Douglas fir, coast	8 x 12	12 x 12	12 x 12	12 x 12	(6 x 12 (8 x 12	1
	Douglas fir, mountain .	10 x 12	12 x 12	12 x 14	14 x 12	do.	do.
	Hemlock	10 x 12	12 x 12	12 x 14	14 x 12	do.	do.
	Tamarack	8 x 12	12 x 12	12 x 12	12 x 12	do.	do.
	Pine	10 x 12	12 x 14	14 x 14	14 x 14	do.	do.
	Pine, southern yellow .	8 x 12	12 x 12	12 x 12	12 x 12	do.	do.
500	Douglas fir, coast	8 x 12	12 x 12	12 x 12	12 x 12	do.	do.
	Douglas fir, mountain .	10 x 12	12 x 12	12 x 14	14 x 12	do.	do.
	Hemlock	10 x 12	12 x 12	12 x 14	14 x 12	do.	do.
	Tamarack	8 x 12	12 x 12	12 x 12	12 x 12	do.	do.
	Pine	10 x 12	12 x 14	14 x 14	14 x 14	do.	do.
	Pine, southern yellow .	8 x 12	12 x 12	12 x 12	12 x 12	do.	do.

The vertical component is 57,200 pounds. Its reactions for the longitudinal girders are determined, and the maximum reaction is then taken as the force that acts on the transverse girders; its reactions are then found. This procedure is necessary because the sheave wheel is not directly over either set of girders. On the basis of the final reactions and the use of the formula $M/f = bd^2/6$, the dimensions of the transverse girders may be found. A 10- by 18-inch or equivalent beam would be necessary. By using diagonals this may be reduced considerably, however. The first reaction from the 57,200-pound load is assumed as acting as a concentrated load on a continuous beam with three supports. It is assumed, further, that the

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load is concentrated at the center of the span, although this is not strictly true. There is no breaking load on the left-span, and the one on the righ span is somewhat to the right of the center. These departures from the ideal conditions are on the side of safety. On the above basis each of the end reactions equals five-sixteenths of the load; the middle reaction equals twenty-two-sixteenths of the load, and the maximum negative bending moment equals 6/32 x Fl foot-pounds, where F= the load and l = the distance between the centers of the middle and end support. The middle reaction thus found is resolved into components that act along the diagonals and strut at the bottom. The diagonals are in compression while the strut must be supplemented with a tension member.

On this basis we find that the transverse girder may be made of 12- by 12-inch pieces and the diagonals of 6- by 8-inch pieces, and that a 1-3/8-inch-diameter rod is required for the tension member.

The size of the longitudinal girders or sheave-wheel supports is determined on the basis of the 57,200-pound component. There are two girders for each wheel, each of which takes half of this load. The solution is foun by applying the formula for bending in a simple beam, from which the size of timber required is found to be 10 by 12 inches in section.

HEAD FRAME FOR AN INCLINED SHAFT

A detailed illustration of a head frame for a shaft inclined 60° from the horizontal is shown in figure 16. This design may be used for any shaft inclination between 50° and 80°. About 80° the data for a vertical-shaft head frame are employed. The size of the members is based on the maximum stresses that arise from these two extremes. The fixed dimensions are: Height to sheave wheels, 36 feet; and width of bottom, 22 feet; for the 60° slope the depth is 29 feet.

Load

A gross load of 4,500 pounds is assumed. This allows for 1 ton of ore and 2,500 pounds for the weight of the skip. The construction shown will prove satisfactory for a load up to 5,500 pounds without altering the size of the members.

Posts

The sizes of the posts are based on a basic allowable compressive stress of 1,200 pounds per square inch.

Sheave-Girder (Detail)

The sheave-girder detail is exactly like that of the vertical head frame and is determined in the same way. One similar to that shown in figure 11 probably will prove satisfactory. The components on which the sizes of the members are determined are those normal to the front posts and parallel to the front posts.

Table 8 gives the essential data for constructing head frames for loads other an shown in the illustrations. The dimensions are based on the premise that the ift-collar dimensions are the same as shown in figure 7. Slightly greater dimenons will not affect the cross-sectional areas of the members appreciably. Small-shaft dimensions constitute an additional safety factor for the material shown. a head frame height greater than 36 feet is necessary, such increase may be made long as the panel spacing does not exceed 12 feet. Closer panel spacing adds rength to the structure.

TABLE 8. - Essential details for various loads

ope ill, unds	Weight, car, skip, cage, pounds	Factor of safety	Rope diameter, inch	Breaking strength of rope, pounds	Size of posts, inches		Sheave wheel		
					Front	Back	Groove diameter, inches	O. D., inches	Weight, pounds
,500	2,500	7	5/8	33,200	8 x 8	8 x 8	30	34	201
,500	2,500-4,500	7	3/4	47,400	8 x 10	8 x 10	36	40	278
,500	4,500-5,500	8	1	84,000	8 x 12	12 x 12	48	53	655
,500	5,500-6,500	8	1	84,000	8 x 12	12 x 12	48	53	655

Sheave-girder detail						Struts, inches	Bracing, inch
rders, nches	Posts, inches	Plates, inches	Bolts, plate, inches	Girder tie rods, foot x inches	Bolts, girder, inches		
x 12	8 x 10	4-86 x 6 x 1-1/8	16 x 1	6-1/2 x 1-3/8	10-1	4 x 8	3/4 rod
x 12	10 x 10	4-90 x 7 x 1-3/8	16-1/2 x 1-3/8	6-1/2 x 1-1/4	10-1-1/4	6 x 10	3/4
x 12	12 x 12	4-94 x 9 x 1-5/8	2-19 x 1-1/4	8-1/6 x 1-1/4	10-1-1/4	6 x 12	1
x 12	12 x 12	4-94 x 9 x 1-5/8	2-19 x 1-1/4	8-1/6 x 1-1/4	10-1-1/4	6 x 12	1

Footings

Front posts			Back posts			
Top	Bottom	Depth	Top	Bottom	Depth	Base plate, inches
1/2 in.	1 ft.9 in.	11 in.	1 ft.2 in.	3 ft.	1 ft.10 in.	10x10x1 3/8
1/2 in.	2 ft.	1 ft.2 in.	1 ft.5 in.	3 ft.9 in.	2 ft.8 in.	11x13x1 1/2
ft.5 in.	2 ft.8 in.	1 ft.6 in.	1 ft.10 in.	4 ft.11 in.	3 ft.2 in.	15 1/2x15 1/2x1 1/2
ft.5 in.	2 ft.8 in.	1 ft.6 in.	1 ft.10 in.	4 ft.11 in.	3 ft.2 in.	15 1/2x15 1/2x1 1/2

Table 9 and figure 2 supplement the information given in table 8. By using igure 2 the proper location of the hoisting drum may be determined. The data, as iven, are only for a rope angle of about 45°, although a degree one way or the other s of no material importance. If sheave wheels of a diameter larger than recommended n table 9 are used, the dimensions represented by "A" must be increased. A few nches one way or the other will not affect the size of the sheave posts. A large increase in diameter, however, means that new sheave-post sizes must be calculated. The values given for "A" provide enough clearance for the sheave wheels recommended.

TABLE 9. - Principal dimensions for A-type head frames (see fig. 2)

Rope pull, pounds	A	B	C, inches	D	E, feet	F, feet	G, inches	H[1], feet	I[2]	J, inches		K[4], feet
										O.D.[3]	G.D.	
4,500	2'	2'	6	7' 2"	12	36	(23[5] (14	18 1/2	(31'[5] (31' 10"	34	30	22
6,500	2' 4"	2' 4"	6	7' 10"	12	36	14	18 1/2	31' 10"	40	36	22
8,500	2' 10"	2' 4"	6	7' 10"	12	36	14	18 1/2	31' 10"	53	48	22
10,500	2' 10"	2' 4"	6	7' 10"	12	36	14	18 1/2	31' 10"	53	48	22

[1] For rope slope of 45°, $H = 0.414F - G + 5$ ft.

[2] $I = F + 1.41r - G - 1.41r' \pm h$, where r = radius of sheave groove in inches; r' = radius of hoist drum in inches; h = distance center of drum is above (-) or below (+) the top of the shaft collar.

For this column and a shaft depth up to 300 feet, drums are taken with same diameter as sheave groove; h was taken 3 feet above collar.

[3] Figure shown should not be exceeded by 2 inches.

[4] Use a post batter of about 2 1/4 inches per foot, or make K great enough so front post footings clear shaft collar.

[5] For style of sheave girder shown in figure 5.

Washers

In the figures, types of washers other than flat ones are indicated by capital letters. Table 10 coordinates such information.

TABLE 10. - Beveled (angle) cast-iron washers

Washer	Angle, degrees
A	30
B	45
C	60
D	90 (flat)

In order to provide uniform bearing between the wood and the washer, the timber must be notched out in most cases.

FOOTINGS (FOUNDATIONS)[10]

For supporting the posts it is probable that concrete footings will prove to be more convenient and economical than wooden sills. The force that acts on the back post is 39,100 pounds. With a bearing stress of 275 pounds per square inch, 39,100/275 = 142 square inches. Thus, 12- by 12-inch posts are required instead of the 8- by 8-inch posts used; an alternative is to employ a bearing plate. If the width of the sill is taken as 10 inches, the sill would have to be 142 ÷ 10 = 14 inches deep to resist shear. The sill would than be 10 by 16 inches, allowing 2 inches for gaining. Bearing plates would be necessary with framing and bolts for fastening the posts to the sill. In addition, the sill should be protected against deterioration from contact with wet ground.

The size of the concrete footings will be based on a concrete mix of 1 : 2: 4 - that is, 1 part cement, 2 parts sand, and 4 parts aggregate (either crushed rock or gravel). For concrete of this mixture an allowable compressive stress of 400 pounds per square inch will be used. The bearing power of the soil that supports the footings will be assumed to be 4,000 pounds per square foot, which is the value usually assumed for clean, dry sand. If the footings are to rest on solid rock, this value may be increased, although for this type of construction it probably should remain at 4,000 pounds. If they are to rest on soft, earthy, damp ground, the allowable pressure may have to be reduced to 1,000 pounds per square foot. The footings should be designed to accommodate the maximum possible stress in the posts. (The weight of the footing for our purpose may be disregarded, although for very heavy footings, bearing area for the footing must be provided to support its weight also). For the front post this is 11,200 pounds and for the back post, 39,100 pounds.

Front Post

Minimum area of top of footing: 11,200/400 = 28 square inches.

The 8- by 8-inch post provides 8 x 8 = 64 square inches of bearing area. The area of the top of the footing should be at least twice the area of the post or of the bearing plate, if one is necessary.

2 x 64 = 128 square inches = 0.89 square foot.

$\sqrt{0.89}$ = 0.95 foot = 11 1/2 inches.

The top will then be 11 1/2 inches square.

Area for the bottom = 11,200/400 = 2.8 square feet.

$\sqrt{2.8}$ = 1.71 feet = 1 foot 9 inches.

The bottom will be 1 foot 9 inches square.

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[10] Staley, W. W., work cited in footnote 4 (p. 3), p. 63.

The depth, d, is found from the formula:

$$d = \frac{b - a}{2} \tan 60^{\circ} = \frac{b - a}{2} \times 1.732$$

where,

b = width of footing base, feet;

a = width of column base, feet;

$$d = \frac{1.71 - 8/12}{2} \times 1.732 = 0.9 \text{ feet} = 11 \text{ inches.}$$

The depth will then be 11 inches.

A 1-inch-diameter rod or pipe that projects 6 inches into both the footing and the post will be used as a dowel to prevent the post from slipping from the footing. This will also be done on the back post.

Back Post

39,100/400 = 97.8 square inches.

The post provides but 64 square inches bearing area. A base plate must therefore be used.

$\sqrt{97.8} = 9.9$ inches or say 10 inches.

The thickness of the base plate is 1 3/8 inches.

2 x 10 x 10 = 200 square inches = 1.39 square feet equals area of top.

$\sqrt{1.39} = 1.18$ feet = 1 foot, 2 inches.

The top will be 1 foot, 2 inches square.

39,100/4,000 = 9.78 feet.

$\sqrt{9.78} = 3.13$ feet = 3 feet, 1-1/2 inches.

The bottom will be 3 feet, 1 1/2 inch square.

$$\text{Depth} = \frac{3 - 10/12}{2} \times 1.732 = 1.87 \text{ feet} = 1 \text{ foot, } 10 \text{ inches.}$$

Material Required for Footings

By means of Fuller's rule the quantity of sand, gravel, and cement may be calculated:

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$$\text{Cement} = \frac{11}{c + s + g} = C \text{ barrels},$$

$$\text{sand} = C \times s \times 3.8/27 \text{ cubic yard},$$

$$\text{gravel} = C \times g \times 3.8/27 \text{ cubic yard},$$

where

C = number of barrels of cement per cubic yard of concrete,

c = proportion of cement in mix,

s = proportion of sand in mix,

g = proportion of gravel in mix,

$$C = \frac{11}{1 + 2 + 4} = 11/7 = 1.57 \text{ barrel},$$

$$\text{sand} = 1.57 \times 2 \times 3.8/27 = 0.44 \text{ cubic yard},$$

$$\text{gravel} = 1.57 \times 4 \times 3.8/27 = 0.88 \text{ cubic yard}.$$

The volume of a footing is

$$V = h/3\,(A + B + \sqrt{A \times B}) \text{ cubic feet},$$

where

h = depth of footing, feet;

A = area of top, square feet;

B = area of bottom, square feet.

For onefront footing,

$$V = 0.9/3\,(0.9 + 2.8 + \sqrt{0.9 \times 2.8}) = 1.6 \text{ cubic feet}.$$

For one back footing,

$$V = 1.9/3\,(1.2 + 9.8 + \sqrt{1.2 \times 9.8}) = 9.5 \text{ cubic feet},$$

$2 \times (1.6 + 9.5) = 22.2$ cubic feet for the four footings,

$22.2/27 = 0.82$ cubic yard of concrete required,

$1.57 \times 0.82 = 1.29$ barrel = 5 sacks of cement, 0.44 x 0.82 = 0.36 cubic yard of sand,

0.88 x 0.82 = 0.72 cubic yard of gravel.

MATERIAL REQUIRED AND COST OF HEAD FRAMES

Tables 11, 12, 13, and 14 give bills of material and costs for typical head frames. The unit prices assumed represent local quotations. The cost of bolts, tie rods, and steel plate closely approximates 10 cents per pound, fabricated. This includes threading, heading, and nuts.

For estimating the painting cost, the total area of the members was determined. It was assumed that 1 gallon of good paint would cover an average of 350 square feet of rough timber, and that three coats would be applied. It was also assumed that 800 square feet of surface could be painted per man per day.

The unit cost for the timber is the local price for tamarack, larch, or local red fir, structural grade. The erection cost of $30 per thousand feet is based on a rate of $1 per hour for skilled labor. For the usual small mine, this probably should be increased to about $60 per thousand.

The actual amount of timber needed was increased 10 percent to allow for waste in framing. In estimating the weight of the head frame, the wood was assumed to weigh 30 pounds per cubic foot.

TABLE 11. - Material and cost of head frame shown in figure 8

MATERIAL

Item	Approximate dimensions, inches x inches x feet	Board feet	Iron, feet	Weight, pounds
posts, front	4 x 6 x 23	92	—	—
posts, back	6 x 6 x 24	144	—	—
struts	6 x 6 x 5 3/4	35	—	—
do.	4 x 6 x 7 3/4	31	—	—
transverse bracings	4 x 6 x 14 3/4	59	—	—
sills	6 x 8 x 14 1/2	116	—	—
sheave beam	6 x 10 x 2 3/4	14	—	—
do.	6 x 10 x 4 3/4	24	—	—
sheave posts	6 x 6 x 4 1/2	27	—	—
Total	—	542	—	1,400
tie rods	3/4 x 7	—	14	21
do.	3/4 x 9	—	18	27
bolts	1 1/4 x 1 3/4	—	14	58
bolts	1 1/4 x 1 1/4	—	5	21
bolts	1 x 1	—	2	5
do.	1 x 1 1/2	—	3	8
do.	1 x 2	—	4	11
do.	1 x 2 1/2	—	3	13
bolts	3/4 x 1	—	4	6
do.	3/4 x 1 1/4	—	5	8
Total	—	—	—	178
0 angle washers . . .	—	—	—	8
4 flat washers . . .	—	—	—	—
sheave wheel	21 inches, O. D.	—	—	80

COST

Item	Quantity	Unit cost	Total cost
imber	542 + (10% x 542) = 600 bd. ft.	$25 per M	$15.00
ie rods and bolts .	178 lb.	10¢ per lb.	17.80
ngle washers. . . .	6 lb.	15¢ per lb.	.90
lat washers	54	2¢ each	1.08
heave wheel	1	$10	10.00
rection	600 board feet	$30 per M	18.00
Total	—	—	62.78

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TABLE 12. - Material and cost of head frame shown in figure 6

MATERIAL

Item	Approximate dimensions, inches x inches x feet	Board feet	Iron, feet	Weight, pounds
2 posts, front . . .	8 x 8 x 40	427	---	---
2 posts, back . . .	8 x 8 x 41	437	---	---
2 struts	4 x 8 x 5-1/4	28	---	---
do.	4 x 8 x 12	64	---	---
do.	4 x 8 x 12-1/2	67	---	---
1 strut	4 x 8 x 13	35	---	---
2 struts	6 x 8 x 16-1/4	130	---	---
1 strut	6 x 8 x 13-1/4	53	---	---
2 struts	6 x 8 x 17-3/4	142	---	---
2 guide posts . . .	8 x 8 x 26	278	---	---
6 guide supports . .	6 x 8 x 8	192	---	---
3 guide post ties .	6 x 6 x 12-1/4	110	---	---
4 guides	4 x 6 x 26	208	---	---
1 sheave beam . . .	10 x 12 x 9	90	---	---
do. . . .	10 x 12 x 11	110	---	---
4 sheave posts . . .	8 x 10 x 4	107	---	---
Total	---	2,478	---	7,000
2 tie rods	3/4 x 8	---	16	24
do.	3/4 x 14-1/2	---	29	44
6 tie rods	3/4 x 16-1/2	---	99	149
2 tie rods	3/4 x 18-1/2	---	37	56
do.	3/4 x 21-1/2	---	43	65
do.	3/4 x 22-1/2	---	45	68
4 tie rods	1-3/8 x 6-3/4	---	27	136
40 bolts	1 x 2-1/4	---	90	240
8 bolts	1 x 1-1/2	---	12	32
2 bolts	1 x 2	---	4	11
do.	1 x 2-1/2	---	5	13
8 bolts	3/4 x 2-1/4	---	18	27
36 bolts	3/4 x 1-3/4	---	63	95
Total	---	---	---	960
4 steel plates . . .	6 x 1-1/8 x 7-1/6	---	---	655
8 steel plate washers	10 x 6 x 1 inches	---	---	135
2 steel plates . . .	10 x 10 x 1-3/8 inches	---	---	92
Total	---	---	---	882
42 angle washers . .	---	---	---	25
140 flat washers . .	---	---	---	---
2 sheave wheels . .	34 inches, O. D.	---	---	402
Gravel	0.72 cu. yd. at 2,700 lb.	---	---	2,000
Sand	0.36 " at 2,400 lb.	---	---	900
Cement	5 sacks at 94 lb.	---	---	470

(Continued -)

TABLE 12. - Material and cost of head frame shown in figure 6 (continued)

COST

Item	Quantity	Unit cost	Total cost
mber	2,478 + (10% x 2,478) = 2,800 bd.ft.	$25 per M	$70.00
eel plates . . .	882 pounds	10¢ per lb.	88.20
e rods and bolts	960 pounds	10¢ per lb.	96.00
gle washers . .	25 pounds	15¢ per lb.	3.75
at washers . . .	140	2¢ each	2.80
eave wheels . .	2	$22	44.00
nd and gravel .	1.08 cubic yard	$3.50 per cu.yd.	3.78
ment	5 sacks	$1 per sack	5.00
int	12 gal.	$3 per gallon	36.00
bor, painting .	6 days	$5 per day	30.00
ection	2,800 board feet	$30 per M	84.00
Total	---	---	$463.53

TABLE 13. - Material and cost of head frame shown in figure 13

MATERIAL

Item	Approximate dimensions, inches x inches x feet	Board feet	Iron, feet	Weight pounds
4 posts, front	8 x 8 x 34	725	—	—
2 posts, back	8 x 8 x 38	405	—	—
2 struts	6 x 8 x 4-1/2	36	—	—
do.	6 x 8 x 10-3/4	86	—	—
6 struts	6 x 8 x 5-1/4	126	—	—
3 struts	6 x 8 x 11-3/4	141	—	—
do.	6 x 8 x 17	204	—	—
2 struts	4 x 8 x 12-1/4	65	—	—
2 guide supports . . .	6 x 8 x 6-3/4	54	—	—
4 guide supports . . .	6 x 6 x 6-3/4	81	—	—
4 guides	4 x 6 x 25-1/2	204	—	—
4 diagonal struts . .	6 x 8 x 10-3/4	163	—	—
2 sheave girder sills	8 x 8 x 7-1/4	77	—	—
do.	12 x 12 x 9	216	—	—
4 sheave girders . . .	10 x 12 x 7-1/4	290	—	—
Total	—	2,873	—	7,300
2 tie rods	3/4 x 11-1/2	—	23	35
do.	3/4 x 17	—	34	51
3 tie rods	3/4 x 18-1/2	—	56	84
1 tie rod	3/4 x 13-1/4	—	13	20
2 tie rods	3/4 x 20-1/2	—	41	62
do.	3/4 x 22	—	44	66
do.	3/4 x 16-1/4	—	33	50
do.	1-3/8 x 13-1/4	—	27	136
do.	3/4 x 6-3/4	—	14	21
18 bolts	3/4 x 1-3/4	—	32	48
16 bolts	3/4 x 1-1/2	—	24	36
8 bolts	1 x 1-1/4	—	10	27
2 bolts	1 x 1-1/2	—	3	8
do.	1 x 2	—	4	11
16 bolts	1 x 2-1/2	—	40	107
4 driftbolts	1 x 1-1/2	—	6	16
8 strap bolts	1 inch dia. x (3" x 1/2") x 3-1/4 ft. at 13 lb.	—	—	104
Total	—	—	—	882
28 angle washers . . .	—	—	—	17
144 flat washers . . .	—	—	—	—
2 sheave wheels . . .	—	—	—	402
Gravel	0.83 cubic yards	—	—	2,200
Sand	.42 cubic yards	—	—	1,000
Cement	6 sacks	—	—	570

(Continued -

TABLE 13. - Material and cost of head frame shown in figure 13 (Continued)

COST

m	Quantity	Unit cost	Total cost
ber	2,873 + (10% x 2,873) = 3,200 board feet	$25 per M	$80.00
rods and bolts	882 pounds	10¢ per lb.	88.20
gle washers . .	17 pounds	15¢ per lb.	2.55
at washers	144	2¢ each	2.88
eave wheels . . .	2	$22	44.00
nd and gravel .	1.25 cubic yards	$3.50 per cu.yd.	4.40
ment	6 sacks	$1 per sack	6.00
int	15 gallons	$3 per gal.	45.00
bor, painting .	7 days	$5 per day	35.00
ection	3,200 board feet	$30 per M	96.00
Total	--	--	$404.03

TABLE 14. - Material and cost of head frame shown in figure 16.

MATERIAL

Item	Approximate dimensions, inches x inches x feet	Board feet	Iron, feet	Weight, pounds
2 posts, front . . .	8 x 8 x 45-1/2	485	—	—
2 posts, back . . .	8 x 8 x 36	385	—	—
2 struts	6 x 8 x 8-1/4	66	—	—
do.	8 x 8 x 18-1/2	197	—	—
do.	4 x 8 x 18-1/2	99	—	—
do.	4 x 8 x 15-3/4	85	—	—
do.	8 x 8 x 15-3/4	170	—	—
do.	8 x 8 x 13-3/4	144	—	—
do.	6 x 8 x 12	96	—	—
4 struts	8 x 8 x 17-1/2	373	—	—
2 struts	6 x 8 x 12-3/4	102	—	—
1 guide sill	10 x 12 x 14-1/2	145	—	—
do.	10 x 12 x 18-3/4	188	—	—
do.	10 x 12 x 23	230	—	—
1 sheave beam	10 x 12 x 9-1/2	95	—	—
do. . . .	10 x 12 x 11	110	—	—
4 sheave posts . . .	10 x 10 x 4	133	—	—
Total	—	3,103	—	7,800
2 tie rods	3/4 x 10-1/4	—	21	32
do.	3/4 x 20-1/2	—	41	62
do.	3/4 x 22-1/4	—	45	68
do.	3/4 x 20-3/4	—	42	63
do.	3/4 x 15	—	30	45
do.	3/4 x 19-1/2	—	39	44
do.	3/4 x 17-1/2	—	35	53
do.	3/4 x 25-1/2	—	51	77
do.	3/4 x 17	—	34	51
do.	3/4 x 21-1/2	—	43	66
do.	3/4 x 24-1/2	—	49	74
4 tie rods	3/4 x 5-3/4	—	23	35
2 bolts	3/4 x 2-1/2	—	5	8
16 bolts	3/4 x 2-1/4	—	36	54
32 bolts	1 x 1-3/4	—	56	150
4 bolts	1 x 2-3/4	—	11	29
do.	1 x 3-1/4	—	13	35
8 bolts	1-1/4 x 1-1/2	—	12	50
Total	—	—	—	996
4 steel plates	10 x 1-1/8 x 8-1/6	—	—	1,250
8 steel plate washers	10 x 6 x 1 inch	—	—	135
50 angle washers . .	—	—	—	30
114 flat washers . .	—	—	—	—
2 sheave wheels . . .	34 inches, O.D.	—	—	402
Gravel	0.72 cubic yards	—	—	2,000
Sand	0.36 cubic yards	—	—	900
Cement	5 sacks	—	—	470

(continued)

TABLE 14. - Material and cost of head frame shown in figure 16. (Continued)

COST

em	Quantity	Unit cost	Total cost
ber	3,103 + (10% x 3,103) = 3,500 board feet	$25 per M	$87.50
rods and bolts	996 pounds	10¢ per lb.	99.60
el plate	1,385 pounds	10¢ per lb.	138.50
le washers	30 pounds	15¢ per lb.	4.50
t washers	114	2¢ each	2.88
ave wheels	2	$22	44.00
d and gravel	1.08 cubic yards	$3.50 per cu.yd.	3.78
ment	5 sacks	$1 per sack	5.00
int	15 gallons	$3 per gal.	45.00
bor, painting	7 days	$5 per day	35.00
ection	3,500 board feet	$30 per M	105.00
Total	---	---	$570.76

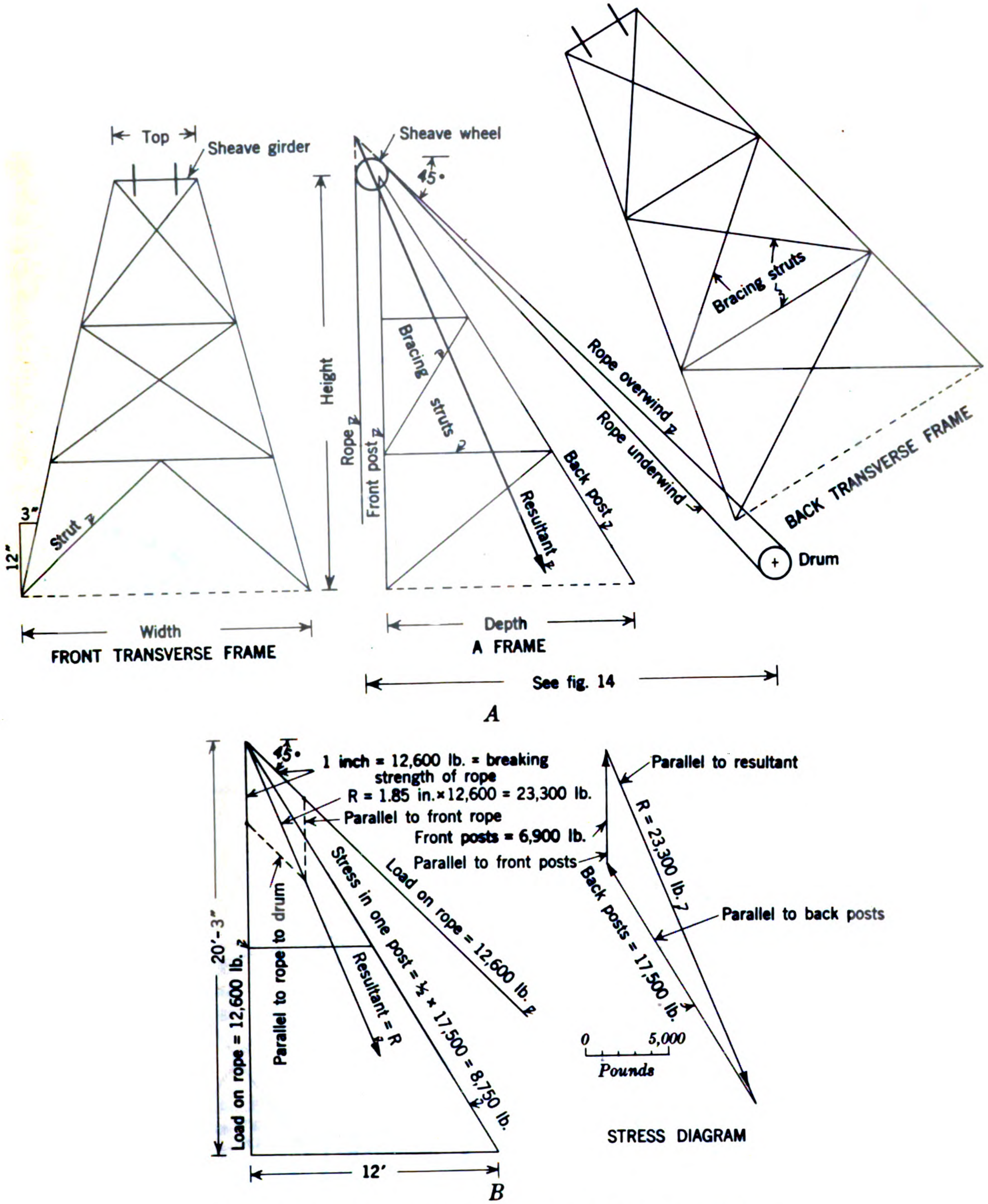


Figure 1.—A-type head frame: *A*, Essential members; *B*, stress diagram.

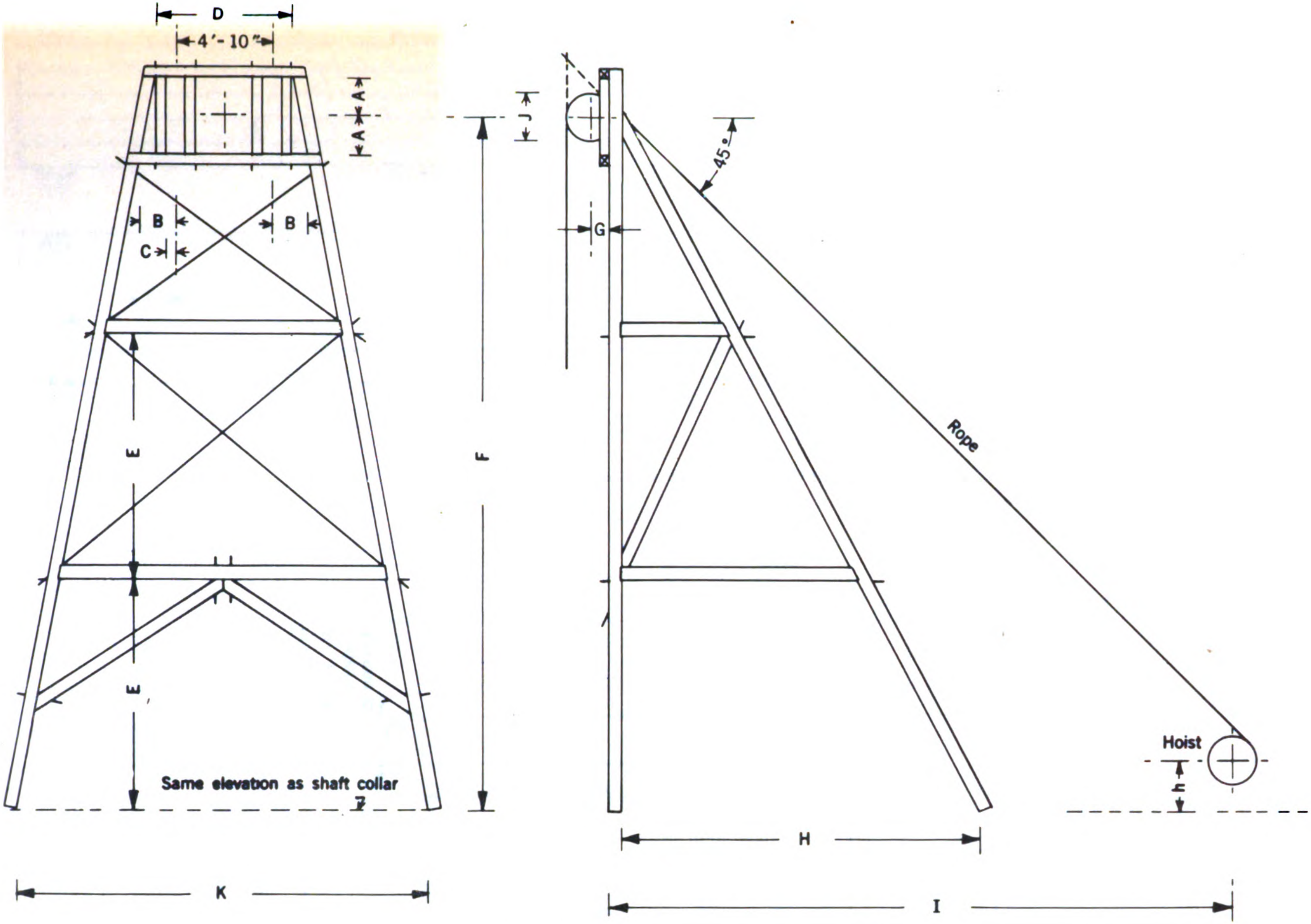


Figure 2.—A-type head frame.

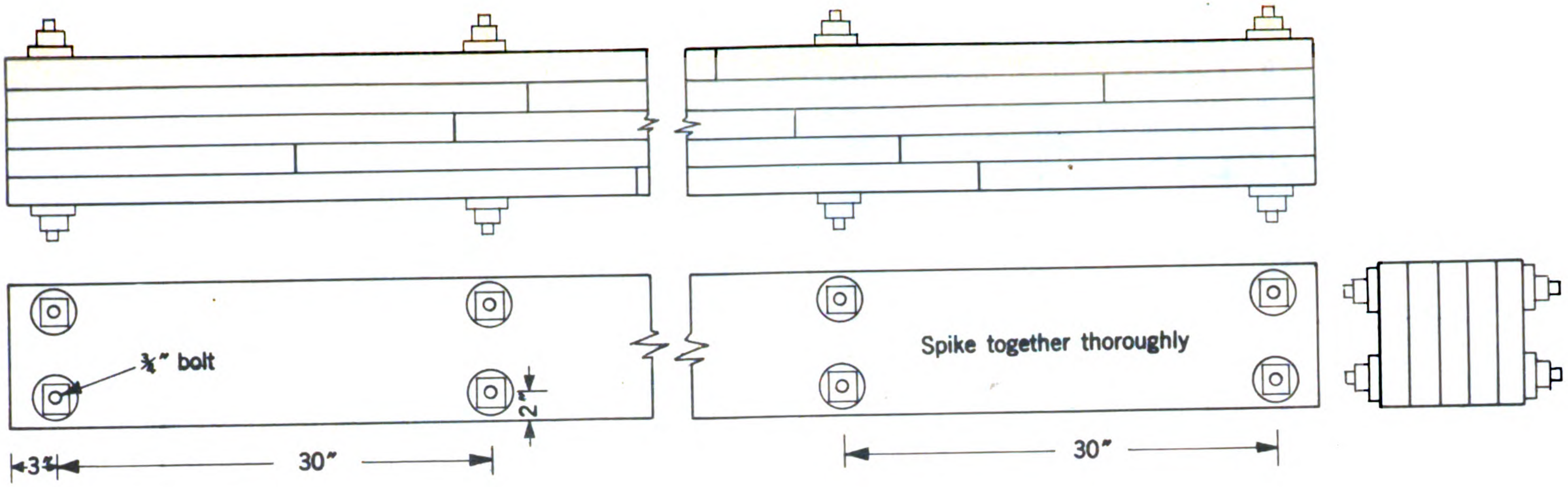


Figure 3.—Construction of laminated column.

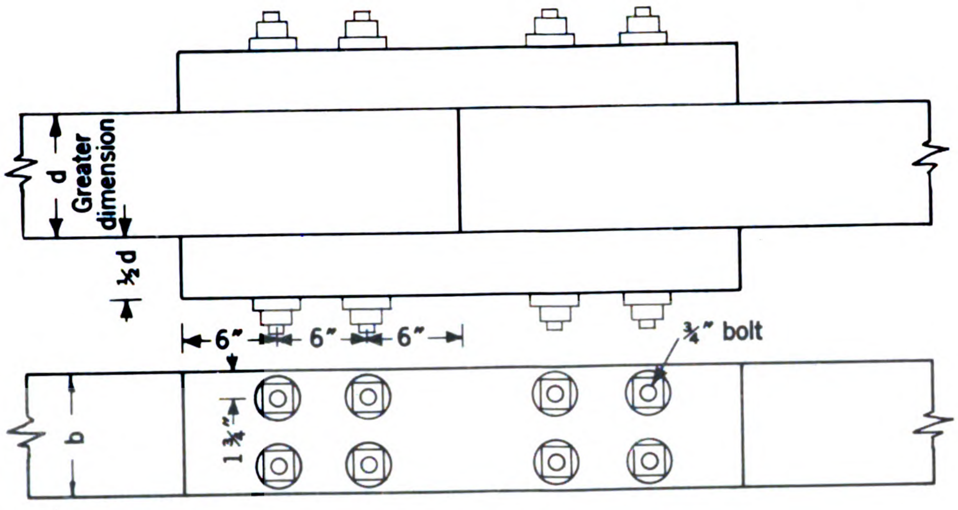
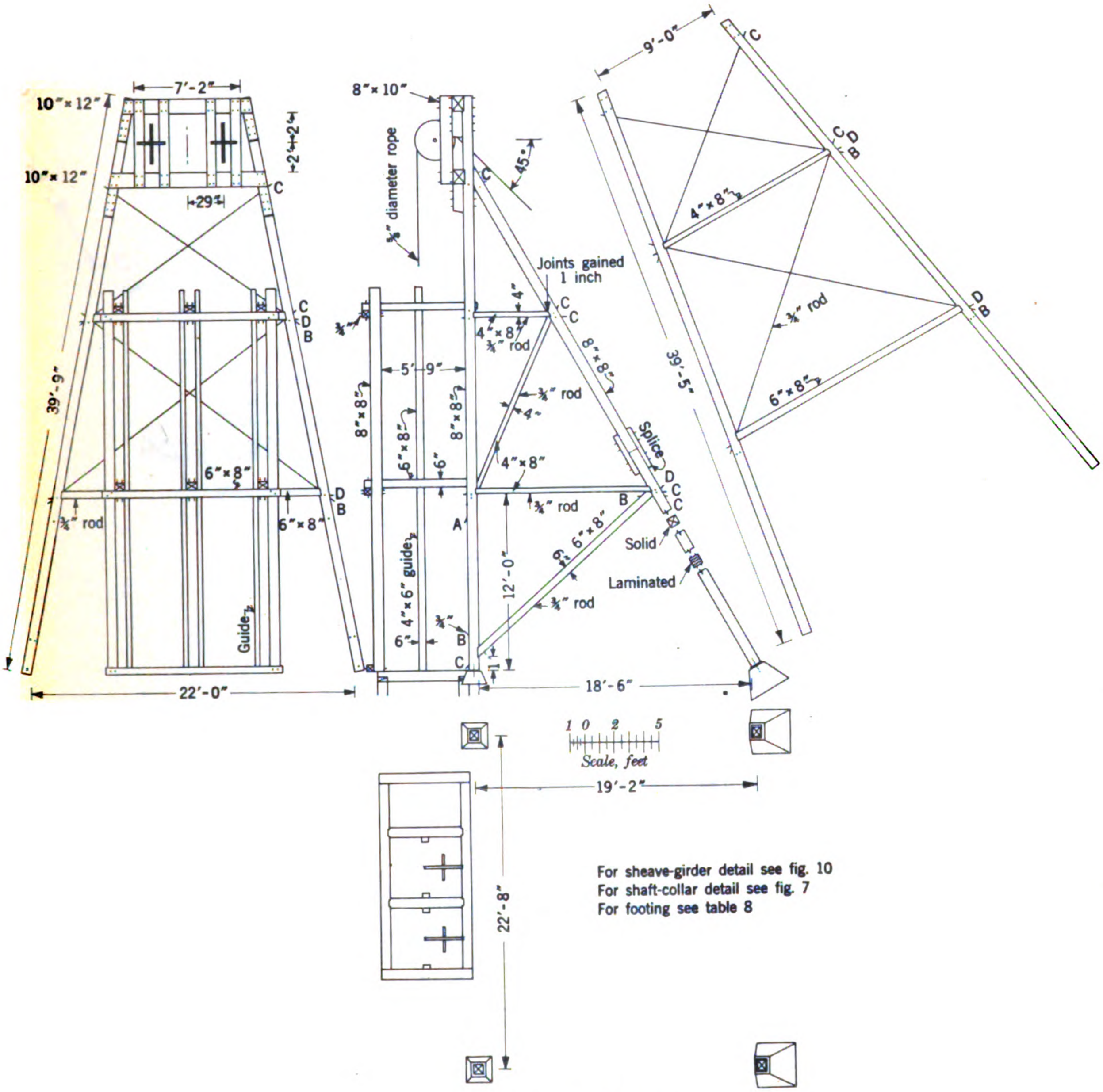
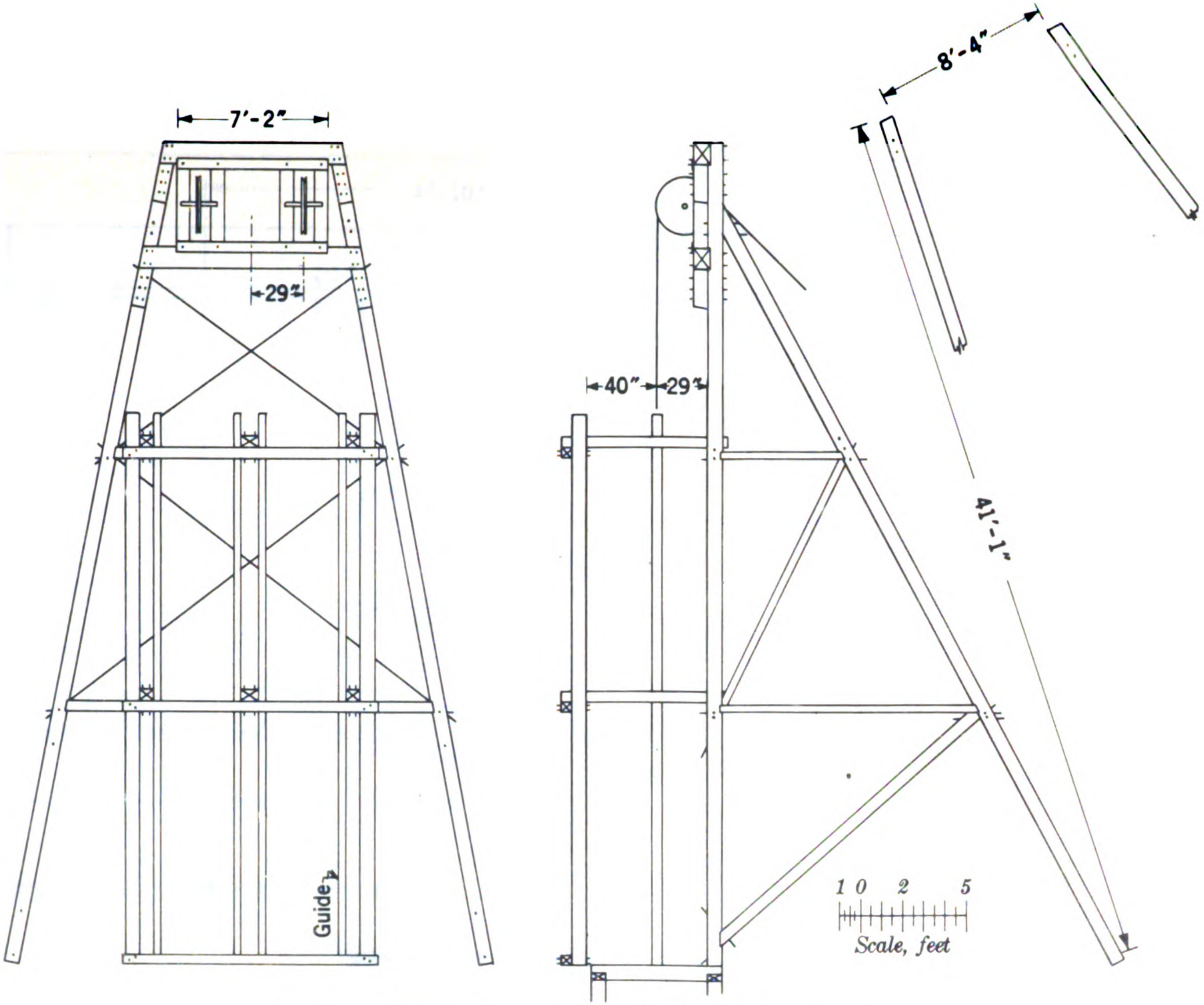


Figure 4.—Details of splice.



For sheave-girder detail see fig. 10
For shaft-collar detail see fig. 7
For footing see table 8

Figure 5.—A-type head frame.



For sheave-girder detail see fig. 11: For other detail see fig. 5

Figure 6.—A-type head frame.

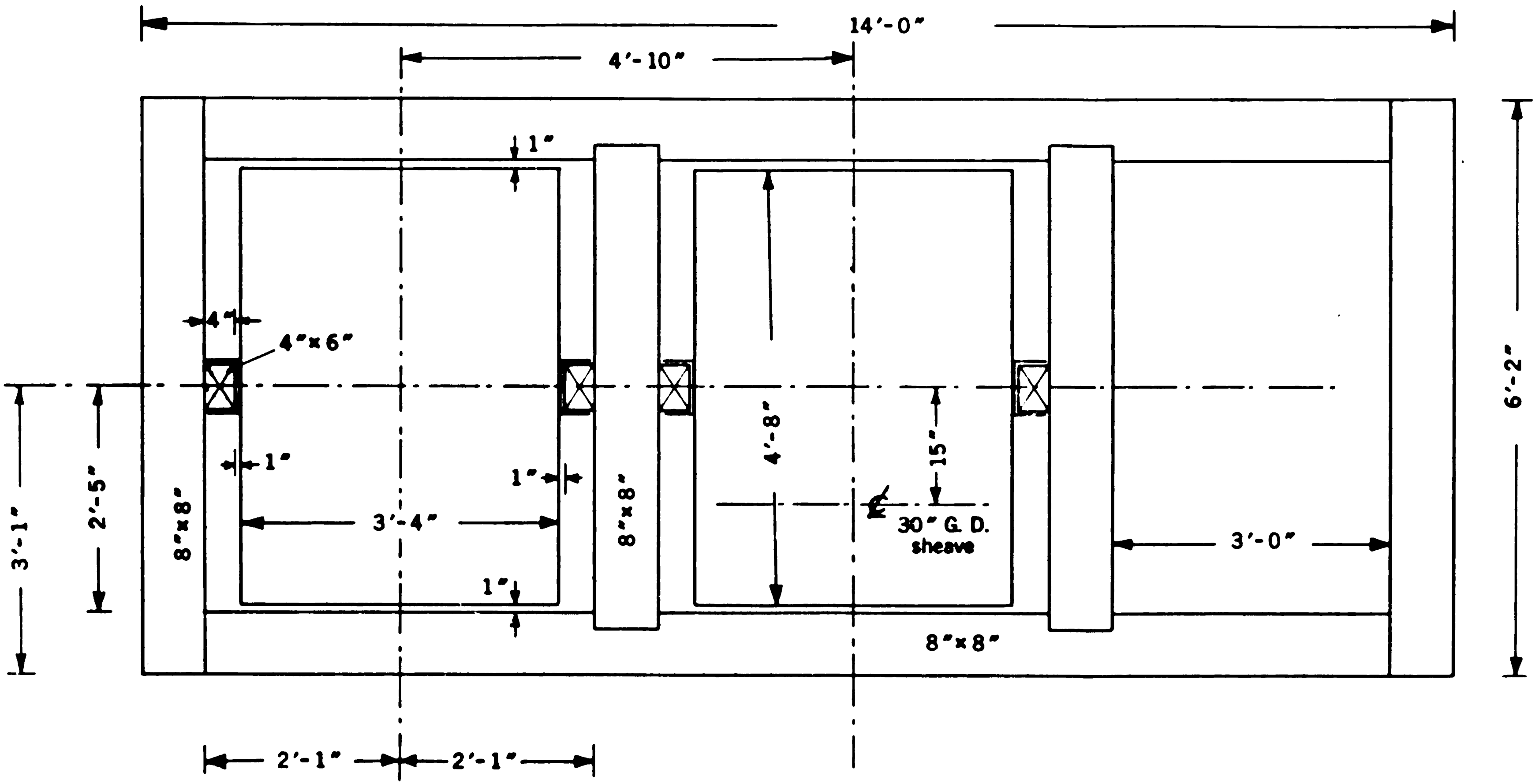


Figure 7.—Shaft collar layout for A-type head frames.

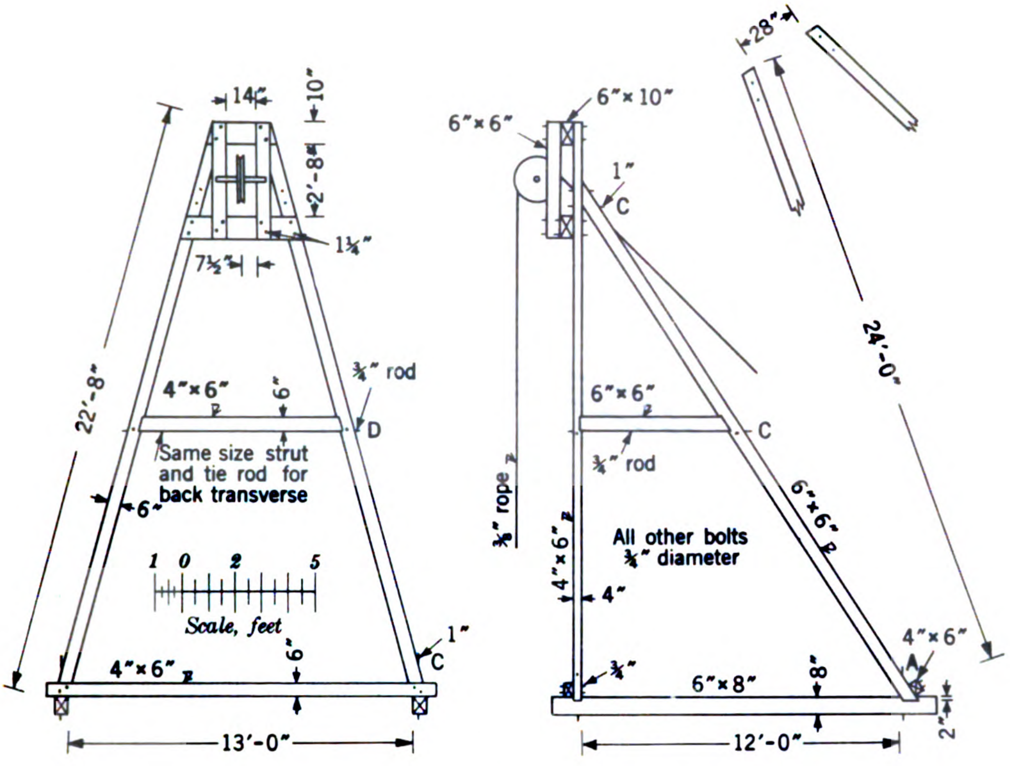


Figure 8.—Small sinking head frame for vertical shaft.

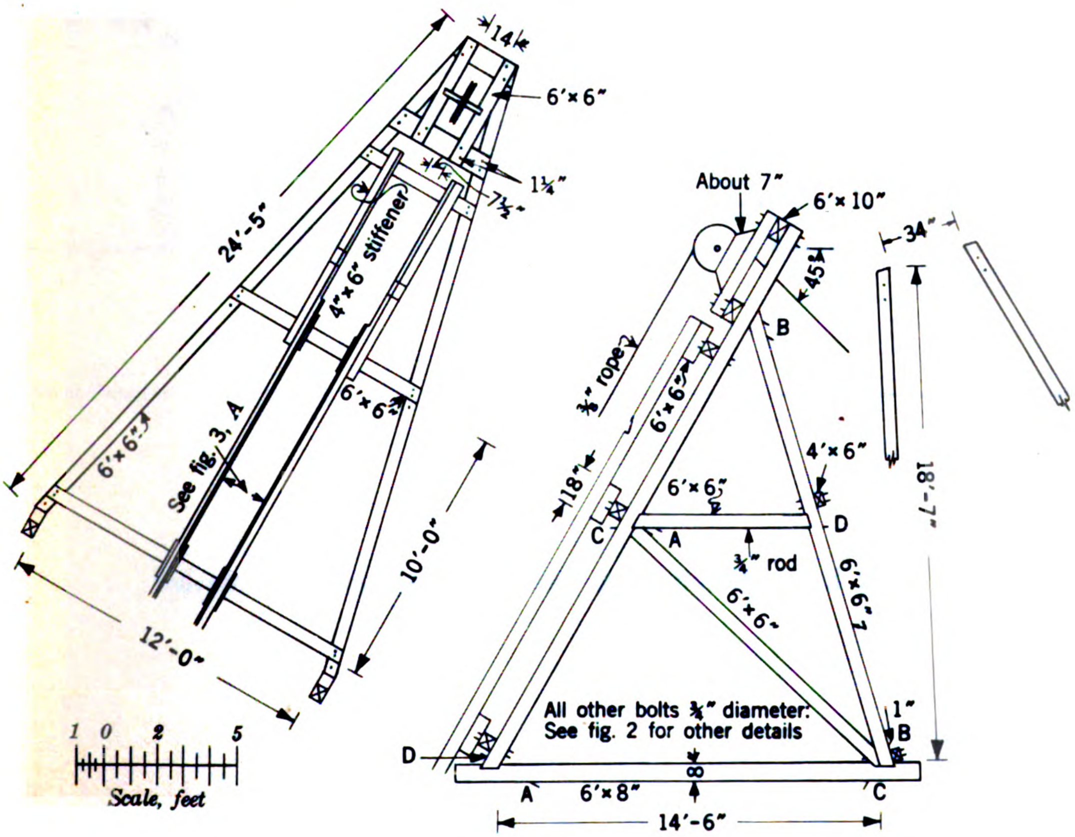


Figure 9.—Small sinking head frame for inclined shaft.

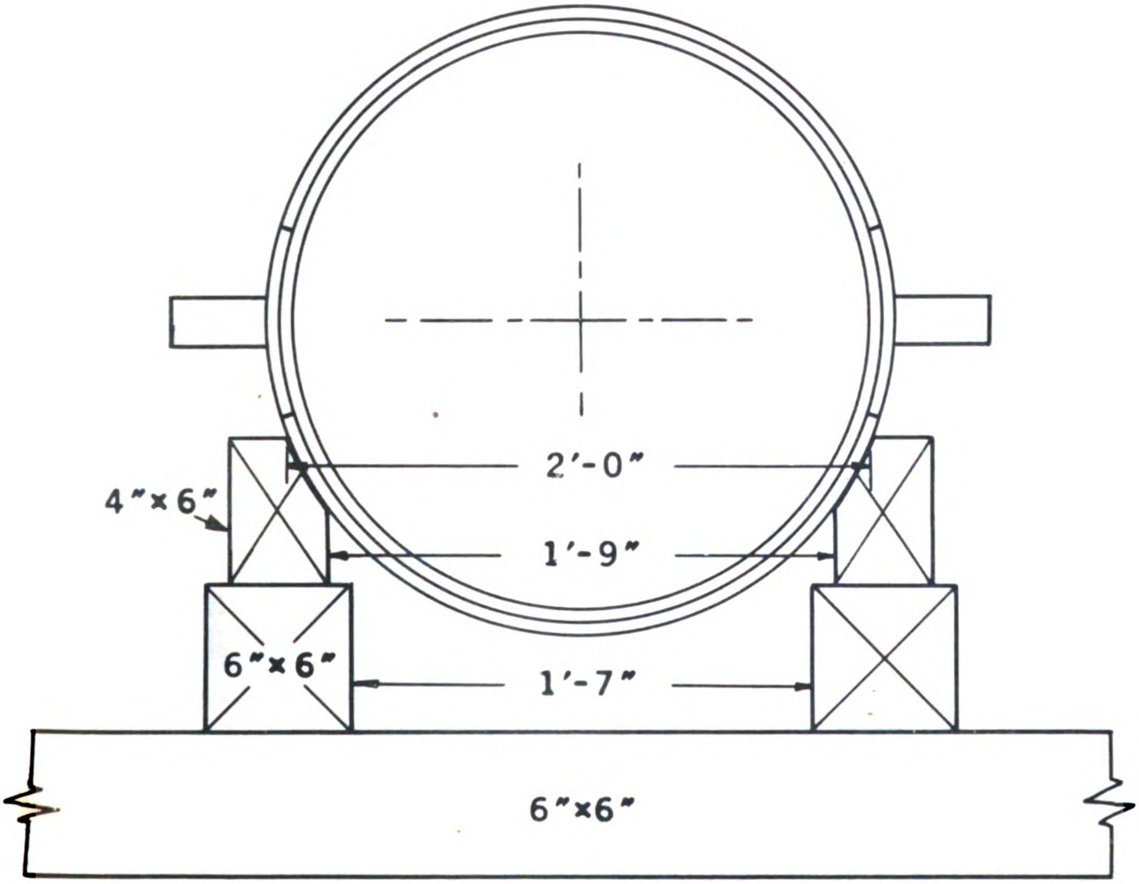


Figure 9a.— Details of guides or skids, inclined shaft.

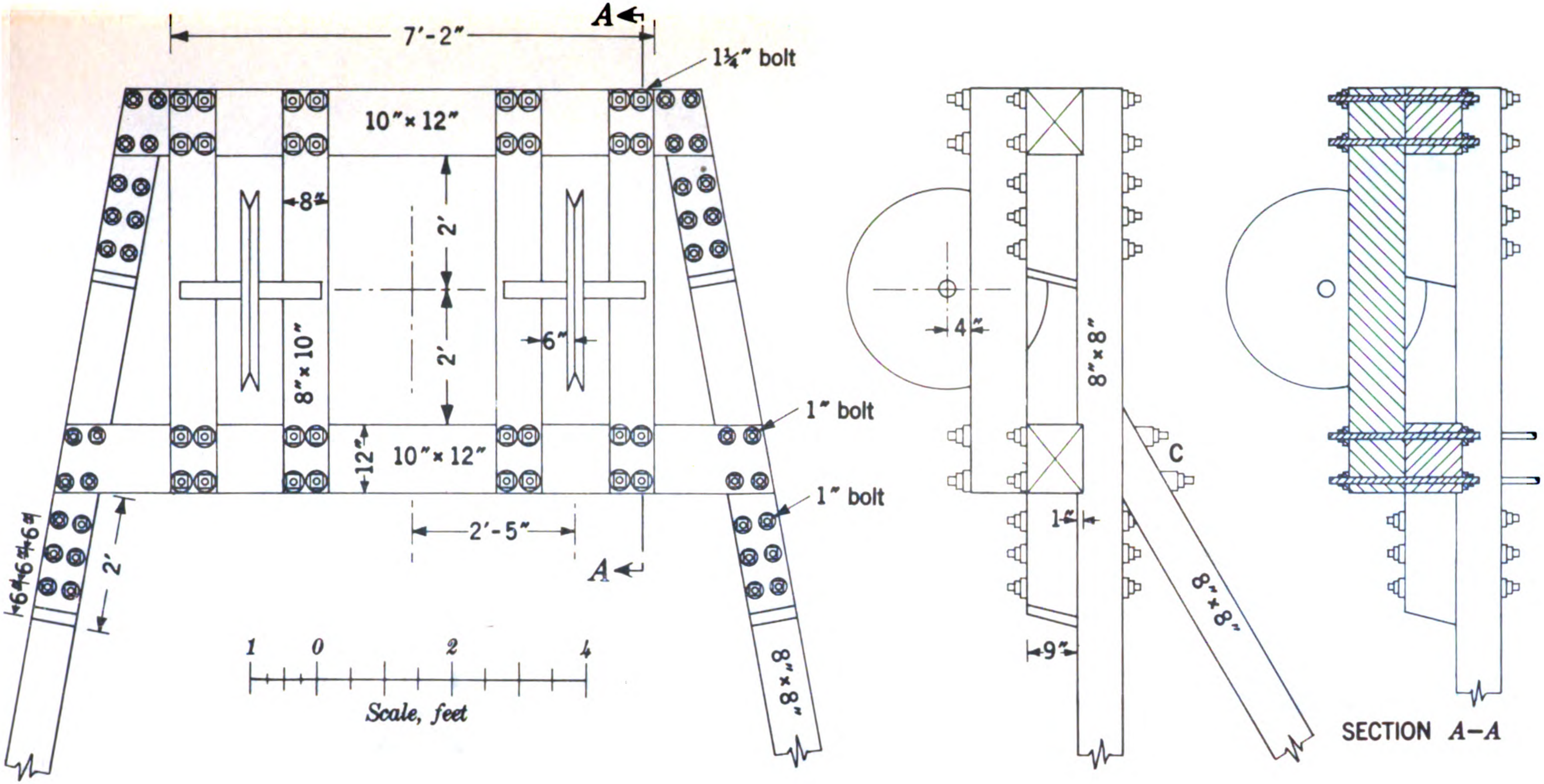


Figure 10.—Sheave-girder details.

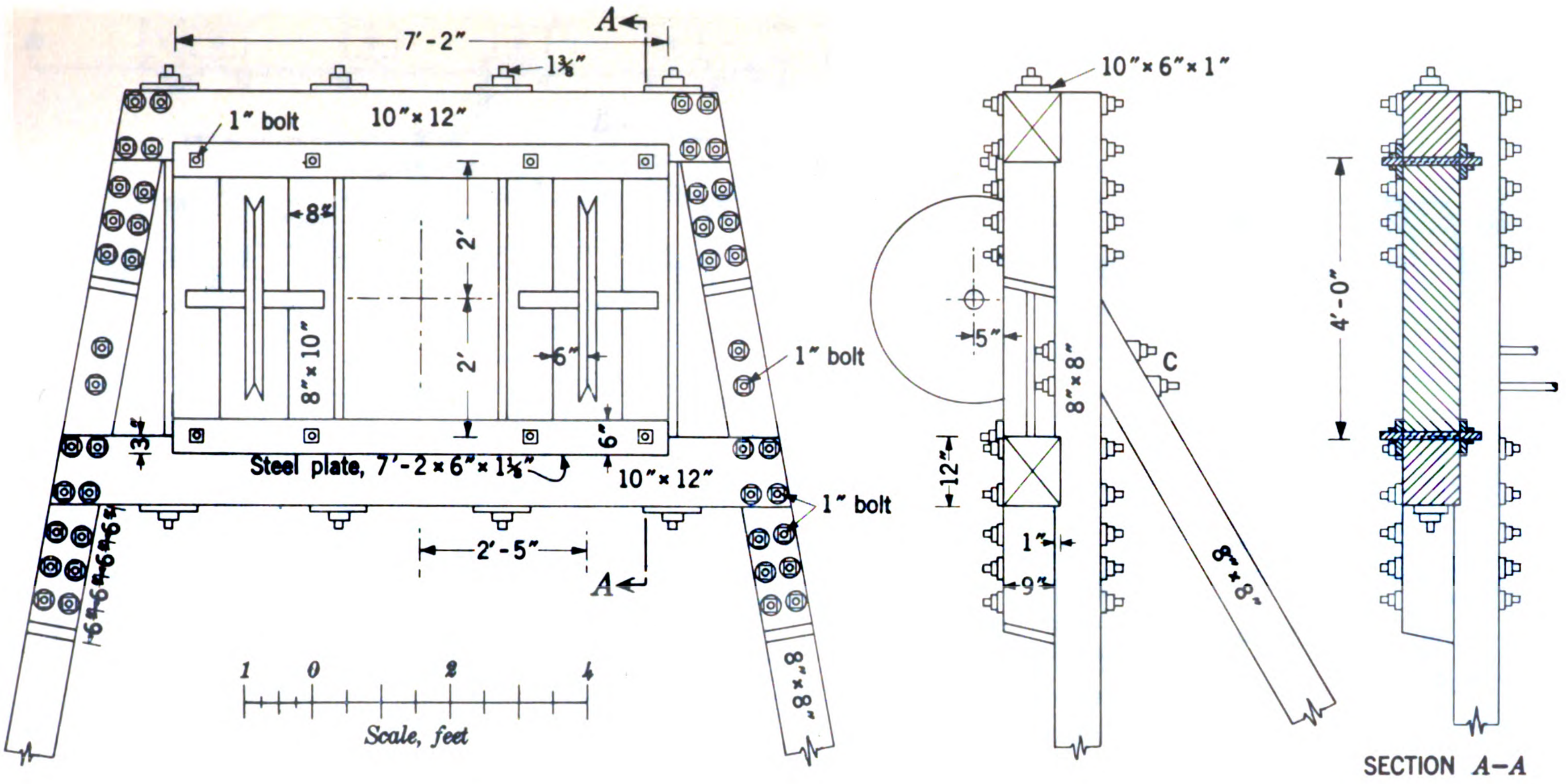


Figure 11.—Sheave-girder details suitable for inclined shaft head frame.

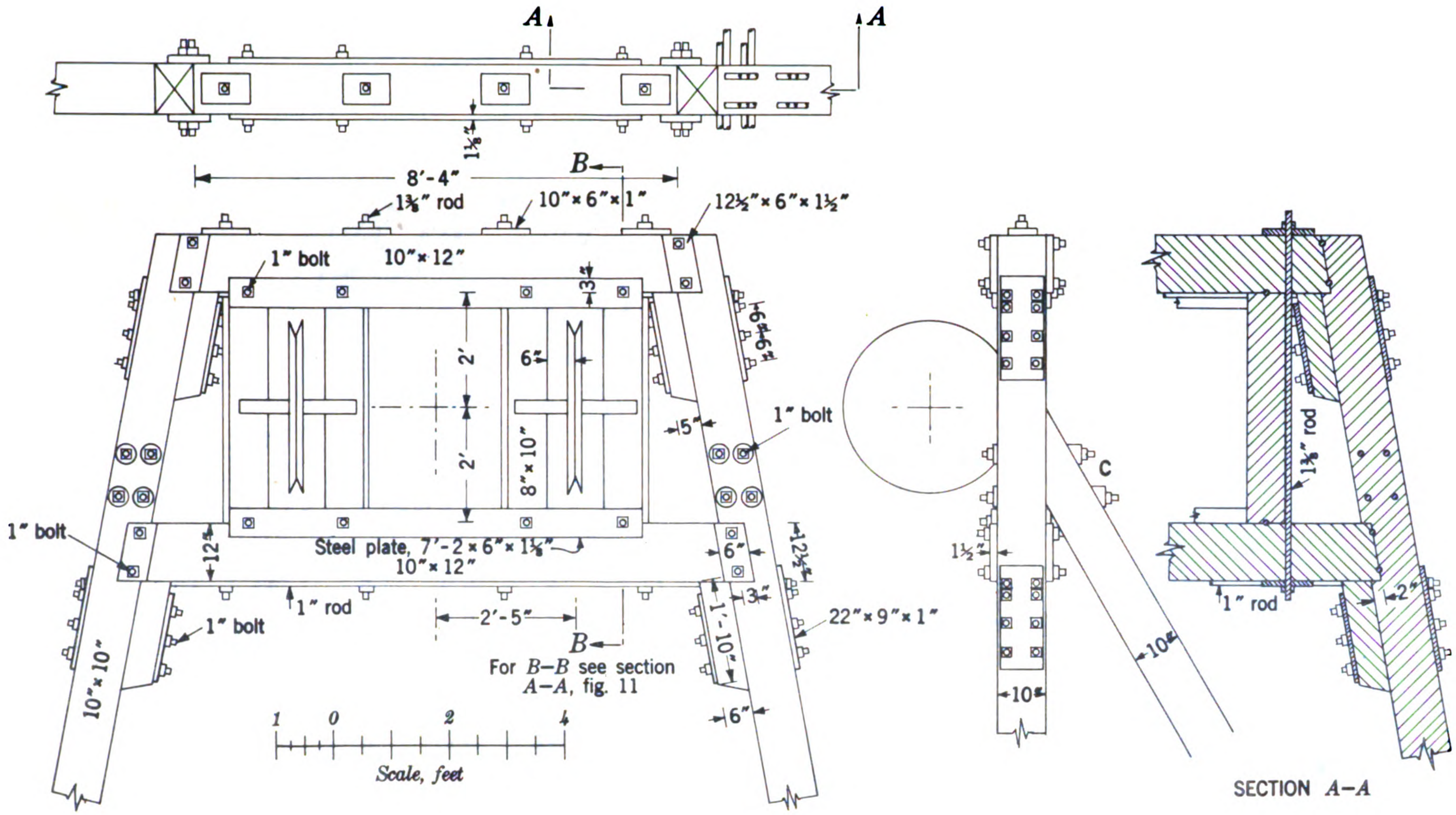


Figure 12.—Sheave-girder details.

Original from THE OHIO STATE UNIVERSITY

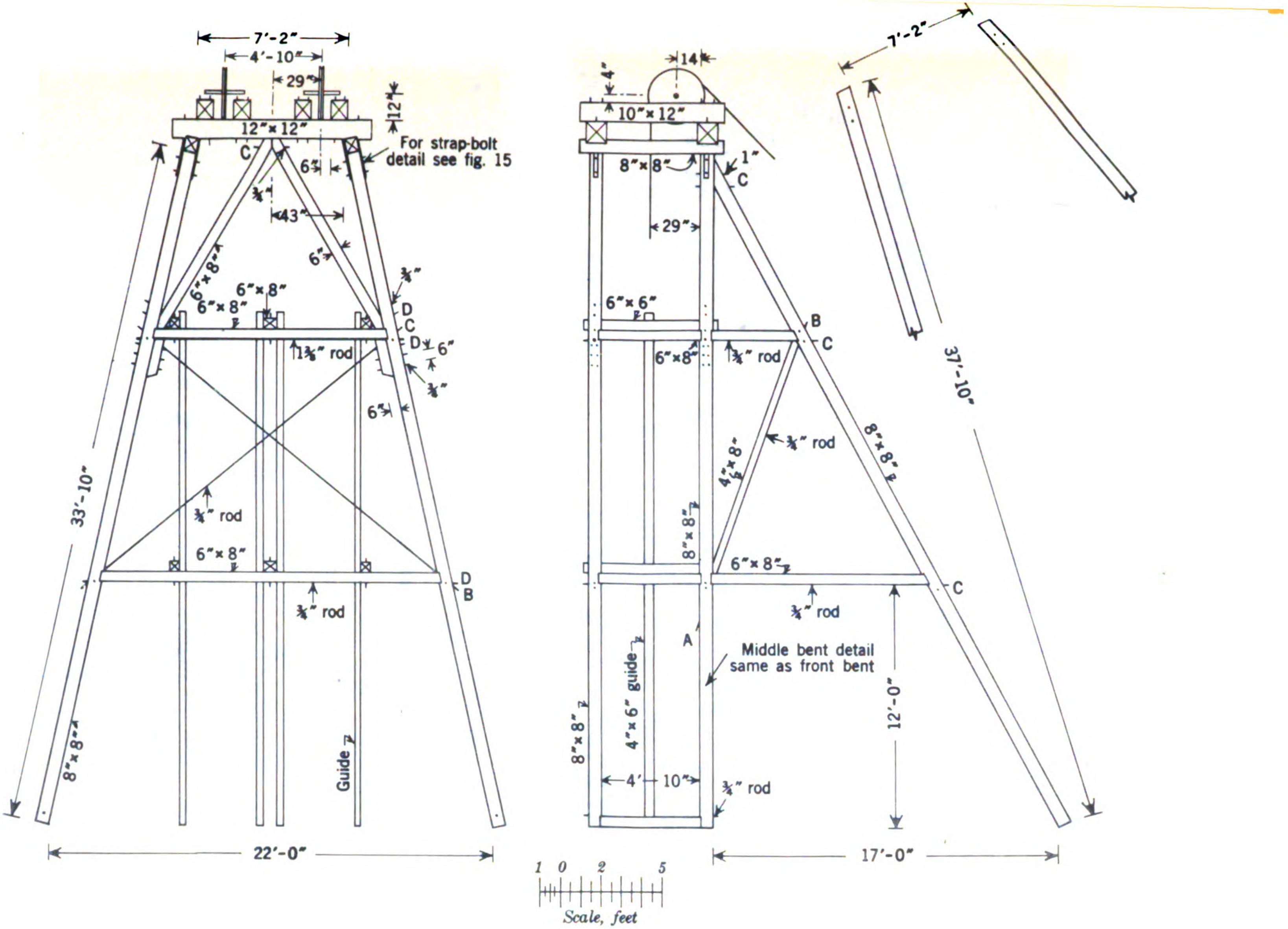


Figure 13.– Four-post head frame.

Original from THE OHIO STATE UNIVERSITY

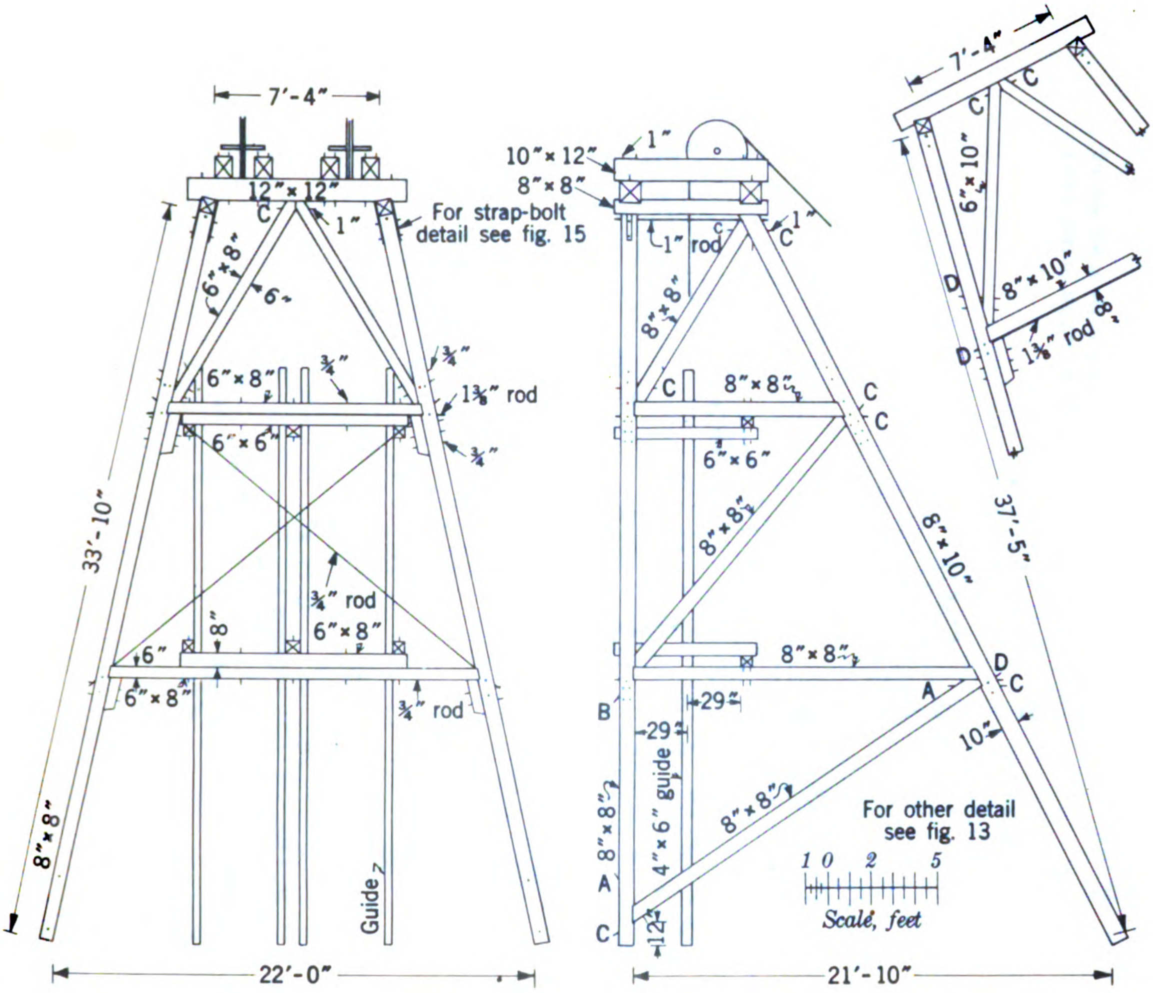


Figure 14.—Semi-four-post head frame.

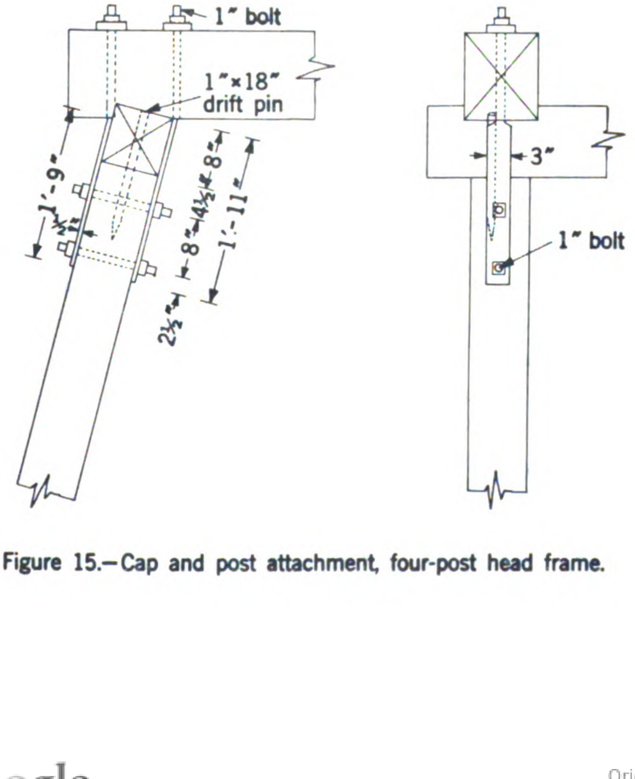
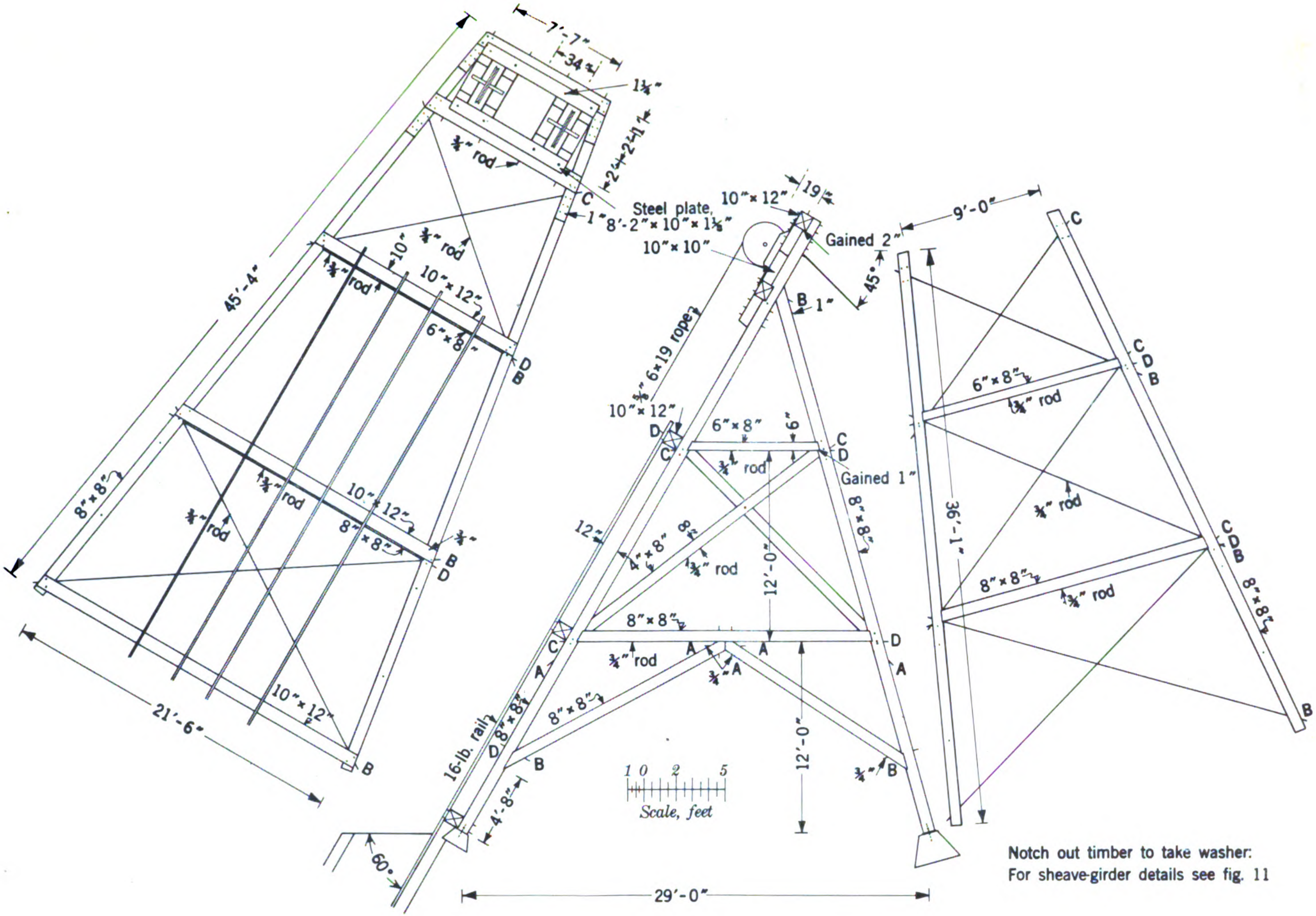


Figure 15.—Cap and post attachment, four-post head frame.



Notch out timber to take washer:
For sheave-girder details see fig. 11

Figure 16.—Head frame for inclined shaft.